THE No 1 UK MAGAZINE FOR ELECTRONICS TECHNOLOGY & COMPUTER PROJECTS

EPE EVERYDAY PRACTICAL ELECTRONICS

www.epemag.com

NEW SERIES:
TEACH-IN 2016
INTRODUCING THE ARDUINO

- Hardware – learn about components and circuits
- Programming – powerful integrated development system
- Microcontrollers – understand control operations
- Communications – connect to PCs and other Arduinos

6-DIGIT RETRO NIXIE CLOCK
60s cool with GPS accuracy

SPARK ENERGY METER
Measure the energy delivered to spark plugs

WIN A MICROCHIP PICDEM Lab II Development Platform

CGA-to-VGA VIDEO CONVERTER
Connect ancient computers to modern VGA monitors

PLUS
INTERFACE, NET WORK, PIC n' MIX, HOT BEANS, CIRCUIT SURGERY, AUDIO OUT, TECHNO TALK & ELECTRONIC BUILDING BLOCKS

FEB 2016 £4.40
02
9 770262 361188

PCBCART

Value-added PCB Fabrication and Assembly from China

More professional | More reliable | Quick turnaround | Less cost

Save **15%** , up to $200 off on your first order
use code **PCBEPE**

- ☑ PCB fabrication up to 32 layers
- ☑ Min. tracing/spacing to 3mil/3mil
- ☑ Min. microvias to 0.1mm
- ☑ Special PCBs-Aluminum, flex and HDI
- ☑ Prototype to mass production
- ☑ Full turnkey PCB assembly

www.pcbcart.com

✉ sales@pcbcart.com

ISSN 0262 3617
● PROJECTS ● THEORY ●
● NEWS ● COMMENT ●
● POPULAR FEATURES ●
VOL. 45. No 2 February 2016

EPE EVERYDAY PRACTICAL ELECTRONICS
INCORPORATING ELECTRONICS TODAY INTERNATIONAL
www.epemag.com

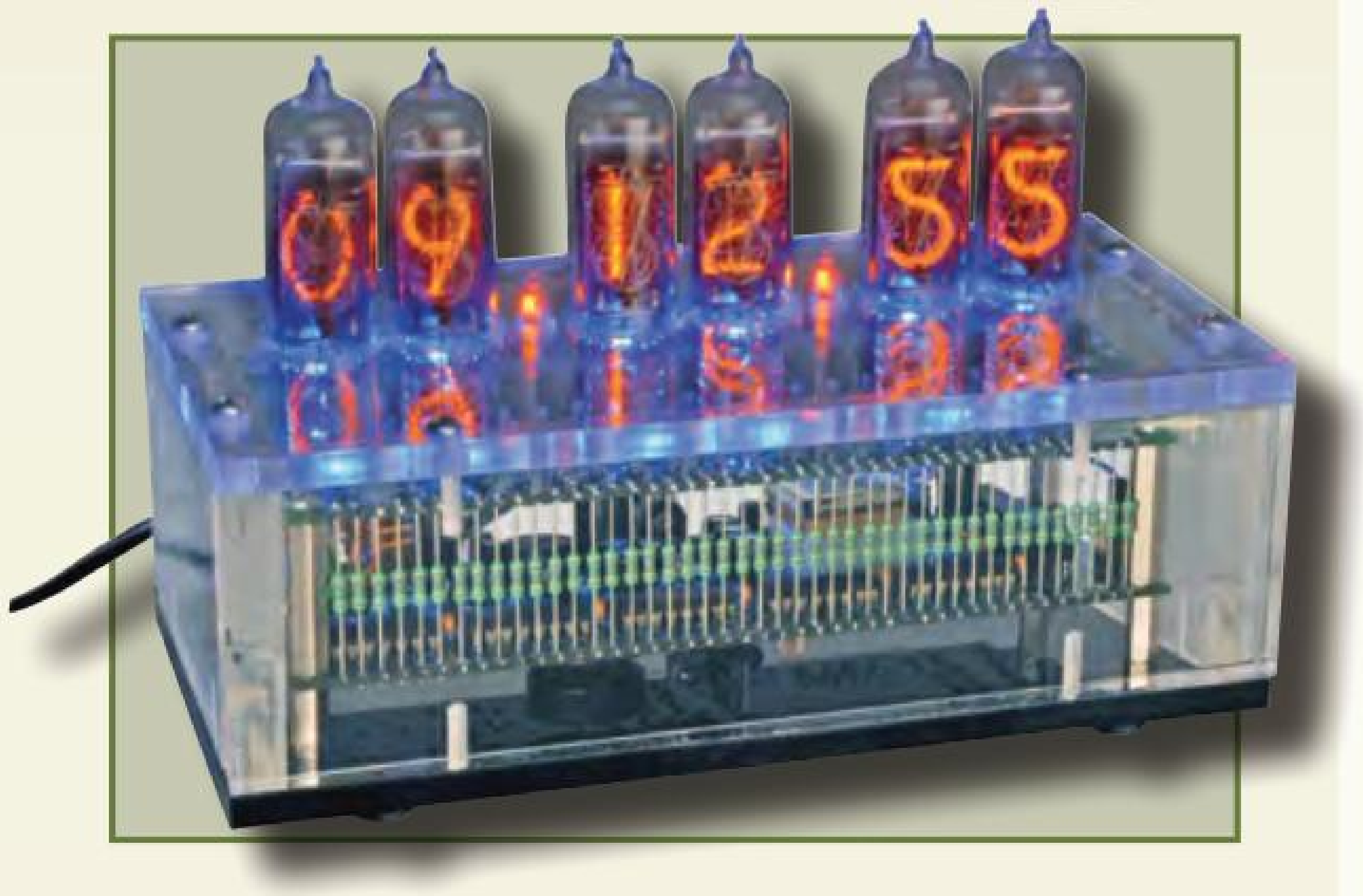
00.0
mJ
SPARK ENERGY METER
POWER
HIGH RANGE

Projects and Circuits

SPARK ENERGY METER – PART 1 11
by Dr Hugo Holden
This meter closely estimates the energy delivered to actual sparks in the ignition system under test, either a CDI or MDI system

6-DIGIT RETRO NIXIE CLOCK – PART 1 20
by Nicholas Vinen
60s cool with 21st-century technology – this fascinating clock design has it all!

CGA-to-VGA VIDEO CONVERTER 32
by Ewan Wordsworth
Connect your old Amiga, Commodore 128, Microbee, Apple or Tandy CoCo 3 computer to any recent model LCD or CRT monitor that has a VGA input



Series and Features

TECHNO TALK by Mark Nelson 18
Golden oldens

GOLD STANDARD – *THE ART OF ELECTRONICS* (3RD EDITION) 39
by Ian Bell

TEACH-IN 2016 – EXPLORING THE ARDUINO 40
by Mike and Richard Tooley
Part 1: Introduction

NET WORK by Alan Winstanley 52
The domain name game... Woolly thinking... Pick your own domain
Countdown to Zero... Printing with Envy

INTERFACE by Robert Penfold 55
BASIC printer port interfacing

CIRCUIT SURGERY by Ian Bell 58
SMT ferrite beads

PIC n' MIX by Mike O'Keeffe 63
Managing software

AUDIO OUT by Jake Rothman 66
Speaking volumes – Part 3

MAX'S HOT BEANS by Max The Magnificent 70
Good Grief! Is that the time?... The painful part of prototyping...
Simblee marvelous, my dear!

ELECTRONIC BUILDING BLOCKS by Julian Edgar 76
Pulsing Timer Module

VGA Video Converter
RGB In
Analog
Digital

Regulars and Services

SUBSCRIBE TO *EPE* and save money 4

EDITORIAL 7
Preferred numbers and the E series

NEWS – Barry Fox highlights technology's leading edge 8
Plus everyday news from the world of electronics

MICROCHIP READER OFFER 31
EPE Exclusive – Win a Microchip PICDEM Lab II Development Platform

CD-ROMS FOR ELECTRONICS 72
A wide range of CD-ROMs for hobbyists, students and engineers

***EPE* PCB SERVICE** 78
PCBs for *EPE* projects

ADVERTISERS INDEX 79

NEXT MONTH! – Highlights of next month's *EPE* 80

Teach-In 2016
Exploring the Arduino
Part 1: Introduction

© Wimborne Publishing Ltd 2016. Copyright in all drawings, photographs and articles published in *EVERYDAY PRACTICAL ELECTRONICS* is fully protected, and reproduction or imitations in whole or in part are expressly forbidden.

Our March 2016 issue will be published on Thursday 4 February 2016, see page 80 for details.

Readers' Services • Editorial and Advertisement Departments *7*

QUASAR
electronics
Solutions for Home, Education & Industry Since 1993

Quasar Electronics Limited
PO Box 6935, Bishops Stortford
CM23 4WP, United Kingdom
Tel: 01279 467799
Fax: 01279 267799
E-mail: sales@quasarelectronics.co.uk
Web: www.quasarelectronics.co.uk

All prices INCLUDE 20.0% VAT. Free UK delivery on orders over £50
Postage & Packing Options (Up to 0.5Kg gross weight): **UK Standard 3-7 Day Delivery** - £3.95; **UK Mainland Next Day Delivery** - £8.95; **Europe (EU)** - £12.95; **Rest of World** - £14.95 (up to 0.5Kg).
Order online for reduced price Postage (from just £1!)
Payment: We accept all major credit/debit cards. Make PO's payable to Quasar Electronics Limited.
Please visit our online shop now for full details of over 1000 electronic kits, projects, modules and publications. Discounts for bulk quantities.

01279 Card Sales Line 467799

PIC & ATMEL Programmers

We have a wide range of low cost PIC and ATMEL Programmers. Complete range and documentation available from our web site.

Programmer Accessories:
40-pin Wide ZIF socket (ZIF40W) £9.95
18Vdc Power supply (661.121) £25.95
Leads: Parallel (LDC136) £3.95 / Serial (LDC441) £3.95 / USB (LDC644) £2.95

USB & Serial Port PIC Programmer

USB or Serial connection. Header cable for ICSP. Free Windows software. See website for PICs supported. ZIF Socket & USB lead extra. 16-18Vdc.
Kit Order Code: 3149EKT - £49.95
Assembled Order Code: AS3149E - £64.95
Assembled with ZIF socket Order Code: AS3149EZIF - £74.95

USB PIC Programmer and Tutor Board

This tutorial project board is all you need to take your first steps into Microchip PIC programming using a PIC16F882 (included). Later you can use it for more advanced programming. It programs all the devices a Microchip PICKIT2® can! You can use the free Microchip tools for the PICKit2™ and the MPLAB® IDE environment.
*Order Code: EDU10 - **£55.96***

ATMEL 89xxxx Programmer

Uses serial port and any standard terminal comms program. 4 LED's display the status. ZIF sockets not included. 16Vdc.
*Kit Order Code: 3123KT - **£28.95***
*Assembled Order Code: AS3123 - **£39.95***

Introduction to PIC Programming

Go from complete beginner to burning a PIC and writing code in no time! Includes 49 page step-by-step PDF Tutorial Manual + Programming Hardware (with LED test section) + Windows Software (Program, Read, Verify & Erase) + a rewritable PIC16F84A. 4 detailed examples provided for you to learn from. PC parallel port. 12Vdc.
*Kit Order Code: 3081KT - **£16.95***
*Assembled Order Code: AS3081 - **£24.95***

PIC Programmer Board

Low cost PIC programmer board supporting a wide range of Microchip® PIC™ microcontrollers. Serial port. Free Windows software.
*Kit Order Code: K8076 - **£29.94***

PIC Programmer & Experimenter Board

PIC Programmer & Experimenter Board with test buttons and LED indicators to carry out educational experiments such as the supplied programming examples. Includes a 16F627 Flash Microcontroller that can be reprogrammed up to 1000 times. Software to compile and program your source code is included. Supply: 12-15Vdc.
*Kit Order Code: K8048 - **£23.94***
*Assembled Order Code: VM111 - **£39.12***

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. 12Vdc PSU for all units: Order Code 660.446UK £11.52

USB Experiment Interface Board

5 digital input channels and 8 digital output channels plus two analogue inputs and two analogue outputs with 8 bit resolution.
*Kit Order Code: K8055N - **£25.19***
*Assembled Order Code: VM110N - **£40.20***

2-Channel High Current UHF RC Set

State-of-the-art high security. 2 channel. Momentary or latching relay output rated to switch up to 240Vac @ 10 Amps. Range up to 40m. Up to 15 Tx's can be learnt by one Rx (kit includes one Tx but more available separately). 3 indicator LEDs. Rx: PCB 88x60mm, supply 9-15Vdc.
*Kit Order Code: 8157KT - **£49.95***
*Assembled Order Code: AS8157 - **£54.95***

Computer Temperature Data Logger

Serial port 4-channel temperature logger. °C or °F. Continuously logs up to 4 separate sensors located 200m+ from board. Wide range of free software applications for storing/using data. PCB just 45x45mm. Powered by PC. Includes one DS1820 sensor.
*Kit Order Code: 3145KT - **£19.95***
*Assembled Order Code: AS3145 - **£26.95***
*Additional DS1820 Sensors - **£4.95 each***

Remote Control Via GSM Mobile Phone

Place next to a mobile phone (not included). Allows toggle or auto-timer control of 3A mains rated output relay from any location

Most items are available in kit form (KT suffix) or pre-assembled and ready for use (AS prefix).

4-Ch DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, **Rings** to Answer, Auto Hang-up and Lockout. Includes plastic case. 130 x 110 x 30mm. Power: 12Vdc.
*Kit Order Code: 3140KT - **£79.95***
*Assembled Order Code: AS3140 - **£94.95***

8-Ch Serial Port Isolated I/O Relay Module

Computer controlled 8 channel relay board. 5A mains rated relay outputs and 4 opto-isolated digital inputs (for monitoring switch states, etc). Useful in a variety of control and sensing applications. Programmed via serial port (use our new Windows interface, terminal emulator or batch files). Serial cable can be up to 35m long. Includes plastic case 130x100x30mm. Power: 12Vdc/500mA.
*Kit Order Code: 3108KT - **£74.95***
*Assembled Order Code: AS3108 - **£89.95***

Infrared RC 12–Channel Relay Board

Control 12 onboard relays with included infrared remote control unit. Toggle or momentary. 15m+ range. 112 x 122mm. Supply: 12Vdc/0.5A
*Kit Order Code: 3142KT - **£64.95***
*Assembled Order Code: AS3142 - **£74.95***

Audio DTMF Decoder and Display

Detect DTMF tones from tape recorders, receivers, two-way radios, etc using the built-in mic *or* direct from the phone line. Characters are displayed on a 16 character display as they are received and up to 32 numbers can be displayed by scrolling the display. All data written to the LCD is also sent to a serial output for connection to a computer. Supply: 9-12V DC (Order Code PSU375). Main PCB: 55x95mm.
*Kit Order Code: 3153KT - **£37.95***
*Assembled Order Code: AS3153 - **£49.95***

3x5Amp RGB LED Controller with RS232

3 independent high power channels. Preprogrammed or user-editable light sequences. Standalone option and 2-wire serial interface for microcontroller or PC communication with simple command set. Suitable for common anode RGB LED strips, LEDs and incandescent bulbs. 56 x 39 x 20mm. 12A total max. Supply: 12Vdc.
Kit Order Code: 8191KT - £29.95
Assembled Order Code: AS8191 - £39.95

Hot New Products!

Here are a few of the most recent products added to our range. See website or join our email Newsletter for all the latest news.

4-Channel Serial Port Temperature Monitor & Controller Relay Board

4 channel computer serial port temperature monitor and relay controller. Four inputs for Dallas DS18S20 or DS18B20 digital thermometer sensors (£3.95 each). Four 5A rated relay outputs are independent of sensor channels allowing flexibility to setup the linkage in any way you choose. Simple text string commands for reading temperature and relay control via RS232 using a comms program like Windows HyperTerminal or our free Windows application.

Kit Order Code: 3190KT - ***£84.95***

Assembled Order Code: AS3190 - ***£99.95***

40 Second Message Recorder

Feature packed non-volatile 40 second multi-message sound recorder module using a high quality Winbond sound recorder IC. Standalone operation using just six onboard buttons or use onboard SPI interface. Record using built-in microphone or external line in. 8-24Vdc powered. Change a resistor for different recording duration/sound quality. Sampling frequency 4-12 kHz. (120 second version also available)

Kit Order Code: 3188KT - ***£29.95***

Assembled Order Code: AS3188 - ***£37.95***

Bipolar Stepper Motor Chopper Driver

Get better performance from your stepper motors with this dual full bridge motor driver based on SGS Thompson chips L297 & L298. Motor current for each phase set using on-board potentiometer. Rated to handle motor winding currents up to 2 Amps per phase. Operates on 9-36Vdc supply voltage. Provides all basic motor controls including full or half stepping of bipolar steppers and direction control. Allows multiple driver synchronisation. Perfect for desktop CNC applications.

Kit Order Code: 3187KT - ***£39.95***

Assembled Order Code: AS3187 - ***£49.95***

Video Signal Cleaner

Digitally cleans the video signal and removes unwanted distortion in video signal. In addition it stabilises picture quality and luminance fluctuations. You will also benefit from improved picture quality on LCD monitors or projectors.

Kit Order Code: K8036 - ***£24.70***

Assembled Order Code: VM106 - ***£36.53***

Motor Speed Controllers

Here are just a few of our controller and driver modules for AC, DC, Unipolar/Bipolar stepper motors and servo motors. See website for full details.

DC Motor Speed Controller (100V/7.5A)

Control the speed of almost any common DC motor rated up to 100V/7.5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied. Dimensions (mm): 60Wx100Lx60H.

Kit Order Code: 3067KT - ***£19.95***

Assembled Order Code: AS3067 - ***£27.95***

Bidirectional DC Motor Speed Controller

Control the speed of most common DC motors (rated up to 32Vdc/10A) in both the forward and reverse direction. The range of control is from fully OFF to fully ON in both directions. The direction and speed are controlled using a single potentiometer. Screw terminal block for connections.

Kit Order Code: 3166v2KT - ***£23.95***

Assembled Order Code: AS3166v2 - ***£33.95***

Computer Controlled / Standalone Unipolar Stepper Motor Driver

Drives any 5-35Vdc 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps. Provides speed and direction control. Operates in stand-alone or PC-controlled mode for CNC use. Connect up to six 3179 driver boards to a single parallel port. Board supply: 9Vdc. PCB: 80x50mm.

Kit Order Code: 3179KT - ***£17.95***

Assembled Order Code: AS3179 - ***£24.95***

Computer Controlled Bi-Polar Stepper Motor Driver

Drive any 5-50Vdc, 5 Amp bi-polar stepper motor using externally supplied 5V levels for STEP and DIRECTION control. Opto-isolated inputs make it ideal for CNC applications using a PC running suitable software. Board supply: 8-30Vdc. PCB: 75x85mm.

Kit Order Code: 3158KT - ***£24.95***

Assembled Order Code: AS3158 - ***£34.95***

AC Motor Speed Controller (600W)

Reliable and simple to install project that allows you to adjust the speed of an electric drill or 230V AC single phase induction motor rated up to 600 Watts. Simply turn the potentiometer to adjust the motors RPM. PCB: 48x65mm. Not suitable for use with brushless AC motors.

Kit Order Code: 1074KT - ***£15.95***

Assembled Order Code: AS1074 - ***£23.95***

See website for lots more DC, AC and stepper motor drivers!

QUASAR
electronics
The Electronic Kit Specialists Since 1993

Credit Card Sales 01279 467 799

Electronic Project Labs

Great introduction to the world of electronics. Ideal gift for budding electronics expert!

130-in-1 Electronic Project Lab

Get started on the road to a great hobby or career in electronics. Contains all the parts and instructions to assemble 130 educational and fun experiments and circuits. Build a radio, AM broadcast station, electronic organ, kitchen timer, logic circuits and more. Built-in speaker, 7-segment LED display, two integrated circuits and rotary controls. Manual has individual circuit explanations, schematic and connection diagrams. Requires 6 x AA batteries (not included). Suitable for age 14+.

Order Code EPL130 - ***£55.95***

Also available: *30-in-1* ***£24.95****, 50-in-1* ***£33.95****, 75-in-1* ***£45.95****, 200-in-1* ***£65.95****, 300-in-1* ***£89.95****, 500-in-1* ***£199.95***

Tools & Test Equipment

We stock an extensive range of soldering tools, test equipment, power supplies, inverters & much more - please visit website to see our full range of products.

Advanced Personal Scope 2 x 240MS/s

Features 2 input channels - high contrast LCD with white backlight - full auto set-up for volt/div and time/div - recorder roll mode, up to 170h per screen - trigger mode: run - normal - once - roll ... - adjustable trigger level and slope and much more.

Order Code: APS230 - ***~~£374.95~~ £249.95***

Handheld Personal Scope with USB

Designed by electronics enthusiasts for electronics enthusiasts! Powerful, compact and USB connectivity, this sums up the features of this oscilloscope. 40 MHz sampling rate, 12 MHz analog bandwith, 0.1 mV sensitivity, 5mV to 20V/div in 12 steps, 50ns to 1 hour/div time base in 34 steps, ultra fast full auto set up option, adjustable trigger level, X and Y position signal shift, DVM readout and more...

Order Code: HPS50 - ***~~£289.96~~ £203.95***

See website for more super deals!

No.1 FOR KITS

www.quasarelectronics.co.uk

Secure Online Ordering Facilities • Full Product Listing, Descriptions & Photos • Kit Documentation & Software Downloads

UK readers you can SAVE 81p on every issue of *EPE*

How would you like to pay £3.59 instead of £4.40 for your copy of *EPE*?

Well you can – just take out a one year subscription and save 81p an issue, or £9.80 over the year. You can even save £1.08 an issue if you subscribe for two years – a total saving of £26.10.

Overseas rates also represent exceptional value.

You also:

- **Avoid any cover price increase for the duration of your subscription**
- **Get your magazine delivered to your door each month**
- **Ensure your copy, even if the newsagents sell out**

Order by phone or fax with a credit card or by post with a cheque or postal order, or buy online from www.epemag.com (go to the Online Shop).

SUBSCRIPTION PRICES

Subscriptions for delivery direct to any address in the UK: 6 months £23.50, 12 months £43.00, two years £79.50; Europe Airmail: 6 months £27.00, 12 months £50.00, 24 months £95.00; Rest Of The World Airmail: 6 months £37.00, 12 months £70.00, 24 months £135.00.

Cheques or bank drafts (in **£ sterling only**) payable to *Everyday Practical Electronics* and sent to EPE Subs. Dept., Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Tel: 01202 880299. Fax: 01202 843233. **Email:** subs@wimborne.co.uk. Also via the **Web** at: **www.epemag.com**.

Subscriptions start with the next available issue. We accept MasterCard, Maestro or Visa. (For past issues see the Back Issues page.)

ONLINE SUBSCRIPTIONS

Online subscriptions, for reading the magazine via the Internet, £19.99 for one year, visit **www.epemag.com** for more details.

SUBSCRIPTION ORDER FORM

☐ **6 Months: UK £23.50, Europe £27.00 (Airmail), Rest Of The World £37.00 (Airmail)**
☐ **1 Year: UK £43.00, Europe £50.00 (Airmail), Rest Of The World £70.00 (Airmail)**
☐ **2 Years: UK £79.50, Europe £95.00 (Airmail), Rest Of The World £135.00 (Airmail)**

To: Everyday Practical Electronics,
Wimborne Publishing Ltd., 113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU
Tel: 01202 880299 Fax: 01202 843233
E-mail: subs@epemag.wimborne.co.uk

I enclose payment of £ .... (cheque/PO in £ sterling only), payable to *Everyday Practical Electronics*

☐ Please charge my Visa/Mastercard/Maestro

My card number is: ....
Please print clearly, and check that you have the number correct

Signature ....

Card Security Code .... Valid From Date.......................
(The last 3 digits on or just under the signature strip)

Card Ex. Date ....Maestro Issue No. ....

Name ....

Address ....

Post code .... Tel. ....

Subscriptions can only start with the next available issue.

PEAK®
electronic design ltd

Designed in the UK
Built in the UK

UK designed **and** manufactured

ZEN50 Zener Diode Analyser (inc. LEDs, TVSs etc)

Brand new product!

Introducing the new ***Atlas ZEN*** (model ZEN50) for testing Zeners (including Avalanche diodes) and many other components.

- **Measure Zener Voltage (from 0.00 up to 50.00V!)**
- **Measure Slope Resistance.**
- **Selectable test current: 2mA, 5mA, 10mA and 15mA.**
- **Very low duty cycle to minimise temperature rise.**
- **Continuous measurements.**
- **Single AAA battery (included) with very long battery life.**
- **Gold plated croc clips included.**
- **Can measure forward voltage of LEDs and LED strings too.**

atlas ZEN
model ZEN50
PEAK electronic design ltd
Vz=27.74V @ 15mA
Slope R=53Ω
Zener diode analyser
Zener Voltage
Slope Resistance
Selectable Test Currents
Vz<50V
on - test
scroll - off
warning not for in-circuit

£39.00
£32.50+VAT

PCA23 SOT23 Test Adapter for Multimeters and Peak Analysers

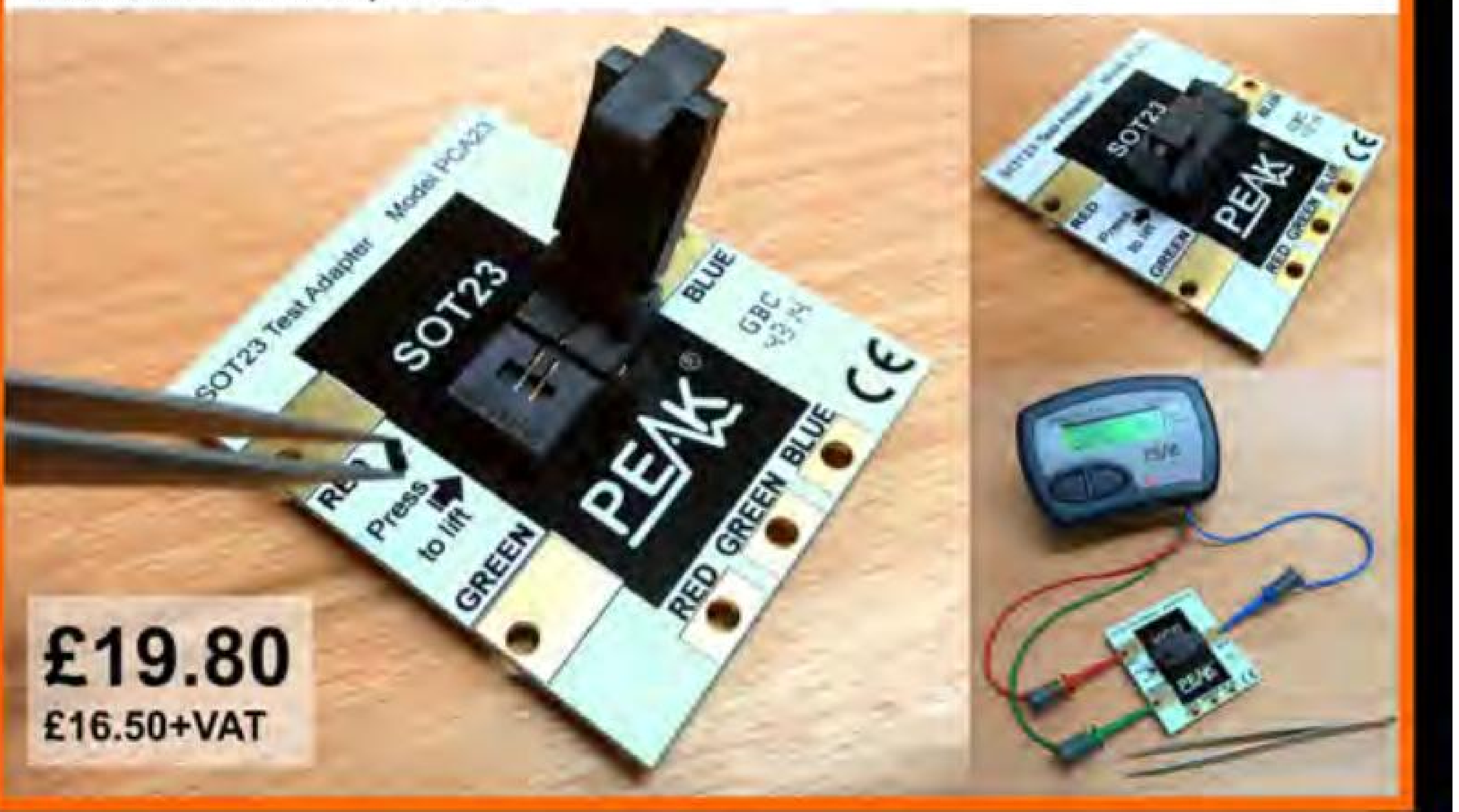
Brand new product!

Designed to look like a giant SOT23 device, this beautiful adapter allows you to easily test your SOT23 surface mounts diodes, MOSFETs and transistors.

Just place your device into the controlled-force clamshell and connect your probes to the gold plated test points.

Great for connecting crocs, hook-probes and meter prods.

Fitted with non-slip feet.


SOT23 Test Adapter Model PCA23
SOT23
PEAK
Press to lift
RED
GREEN
BLUE
RED GREEN BLUE

£19.80
£16.50+VAT

DCA55 Semiconductor Analyser - Identify your semi's

New low price!

Connect any way round to identify the type of component and the pinout! Also measures many parameters including transistor gain, base-emitter voltages, MOSFET thresholds, LED voltages etc. Complete with a comprehensive illustrated user guide. Includes an Alkaline battery so you're ready to go straight away.

- **Transistors (including NPN/PNP, darlingtons, silicon and germanium).**
- **Diodes and LEDs.**
- **MOSFETs.**
- **Measure h_{FE}.**
- **Gold plated hook probes.**
- **Free technical support.**
- **2 year warranty.**

atlas DCA
model DCA55
PEAK electronic design ltd
PNP Darlington Transistor
semiconductor component analyser
automatic lead identification
scroll - off
warning avoid charge/voltages

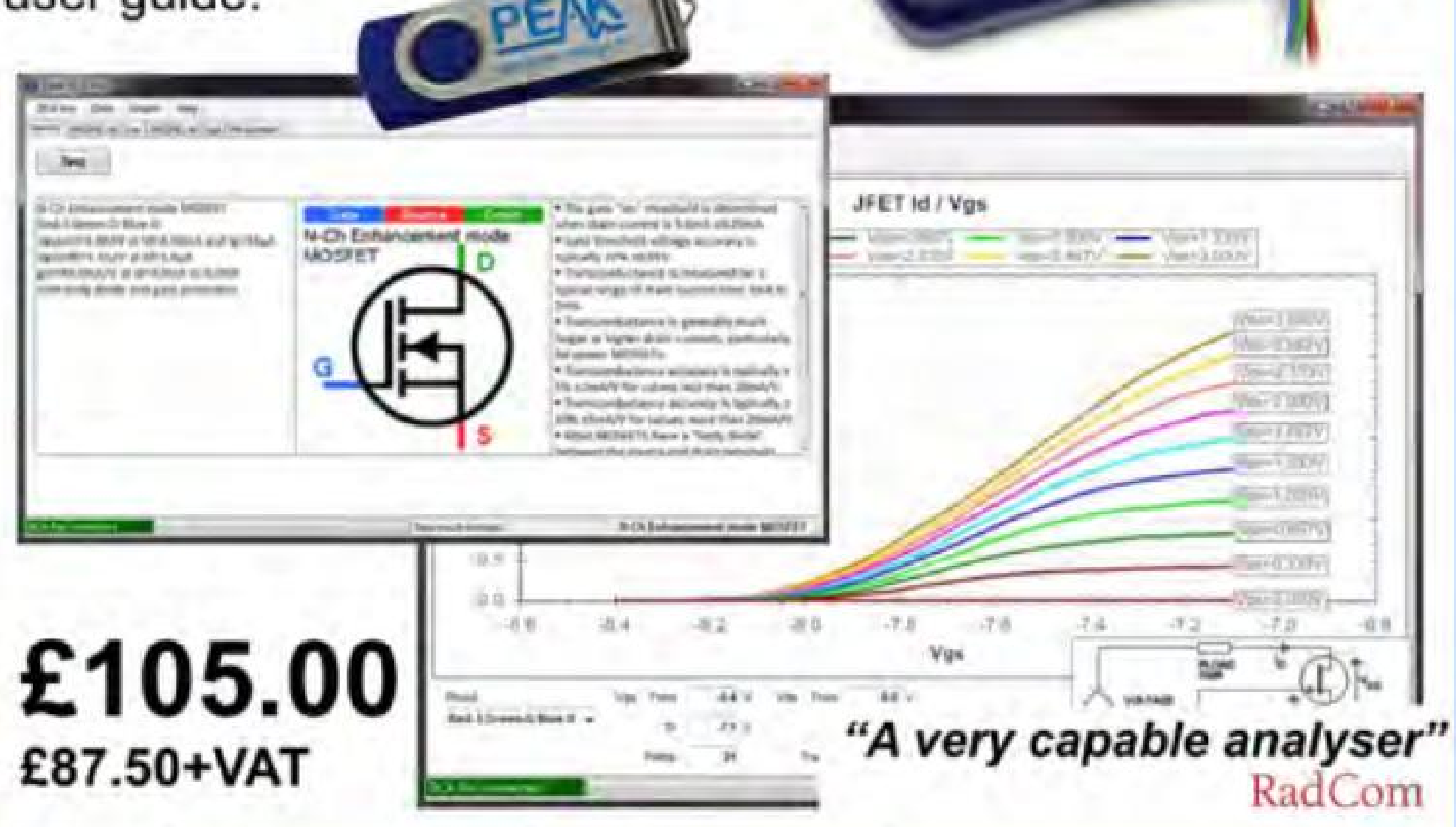
£48.00
£40.00+VAT

DCA75 Advanced Semiconductor Analyser and Curve Tracer

New low price!

The ***DCA Pro*** features a new graphics display showing you detailed component schematics. Built-in USB offers amazing PC based features too such as curve tracing and detailed analysis in Excel. PC software supplied on a USB Flash Drive. Includes Alkaline AAA battery and comprehensive user guide.

atlas DCA Pro
DCA75
PEAK


PEAK
N-Ch Enhancement mode MOSFET
D
G
S
JFET Id / Vgs
Vgs

£105.00
£87.50+VAT

"A very capable analyser"
RadCom

It's only possible to show summary specifications here. Please ask if you'd like detailed data. Further information is also available on our website. Product price refunded if you're not happy.

Tel. 01298 70012
www.peakelec.co.uk
sales@peakelec.co.uk

Atlas House, 2 Kiln Lane
Harpur Hill Business Park
Buxton, Derbyshire
SK17 9JL, UK

Follow us on twitter for tips, tricks and news.
@peakatlas

Sales: 0191 251 4363 Online: www.esr.co.uk/epe

USB PIC Programmer

A PICKit™2 Development Programmer. Features on board sockets for many types of PIC® μcontrollers. Also provided is an ICSP connector, to program your onboard device. USB Powered.

£40.15
Inc Delivery* & VAT

Quote: EPEUSBP

USB PIC Programmer
Velleman

Kits
Boards
Shields
Accessories

Offical Arduino Dealer.
Call for best prices

Arduino Starter Kit

Official Starter kit including 170 page Book, Uno Board Rev3, Breadboard, Components and cables. Everything to get you going with 15 Projects to control the physical world!.

£69.90
Inc Delivery* & VAT

Quote: EPEARDSK

The Arduino Starter Kit

2.4GHz Frequency Counter

0.01Hz to 2.4GHz
8 Digit LED Display
Gate Time: 100ms to 10s
2 Channel Operating mode
Power Supply: 110-220Vac 5W
Quote: EPE24G

£81.00
Inc Delivery* & VAT

DVM13MFC2 HIGH RESOLUTION COUNTER

Velleman LAB1 & LAB2 Bench Instruments

3in1 bench equipment, all you need in a single unit.

LAB1- Multimeter, Power Supply & Soldering Station

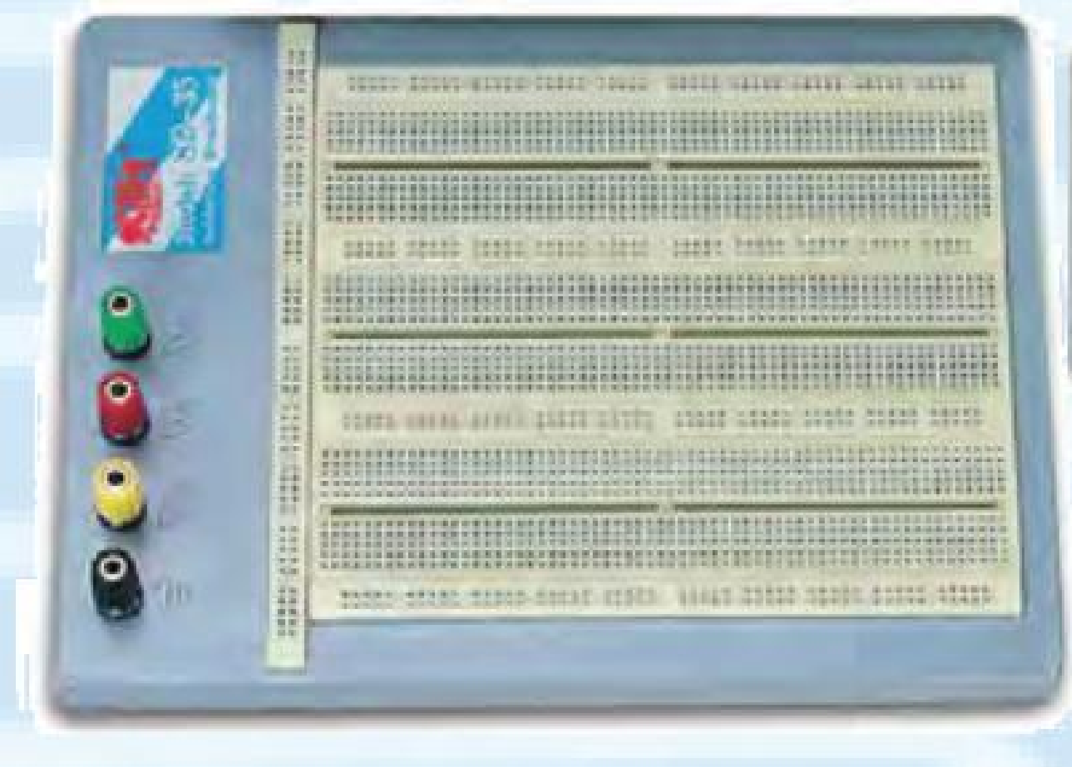
LAB2 - Oscilloscope, Function Generator & PSU

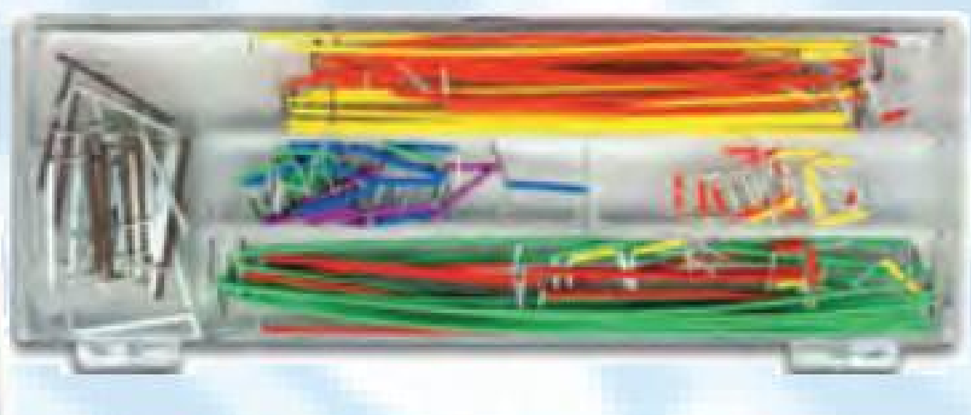
£109.20
Inc Delivery* & VAT

Quote: EPEBLAB1

£146.22
Inc Delivery* & VAT

Quote: EPEBLAB2





SET OF 120 DIODES
Diodes
SET OF 480 RESISTORS E3 SERIES
Resistors
SET OF 100 TRANSISTORS
Transistors
Over 1100 Components
SET OF 120 ELECTROLYTIC CAPACITORS
Capacitors
SET OF 224 CERAMIC CAPACITORS
Capacitors
SET OF 80 ASSORTED LEDs
LEDs

£77.62
Inc Delivery* & VAT

Breadboard & Components Starter Pack

A High Quality Large Breadboard with binding posts, a 140 piece Jump Wire Kit and 6 Component Packs with over 1100 components. Quote: EPEBCS

30V 5A Programmable PSU

Dual LED (Voltage & Current) Displays
Course & Fine V /A Adjustment
5 Programmable Memories
PC Link via USB
or RS232
Output: 0-30Vdc
0-5A

Quote: EPEPSU

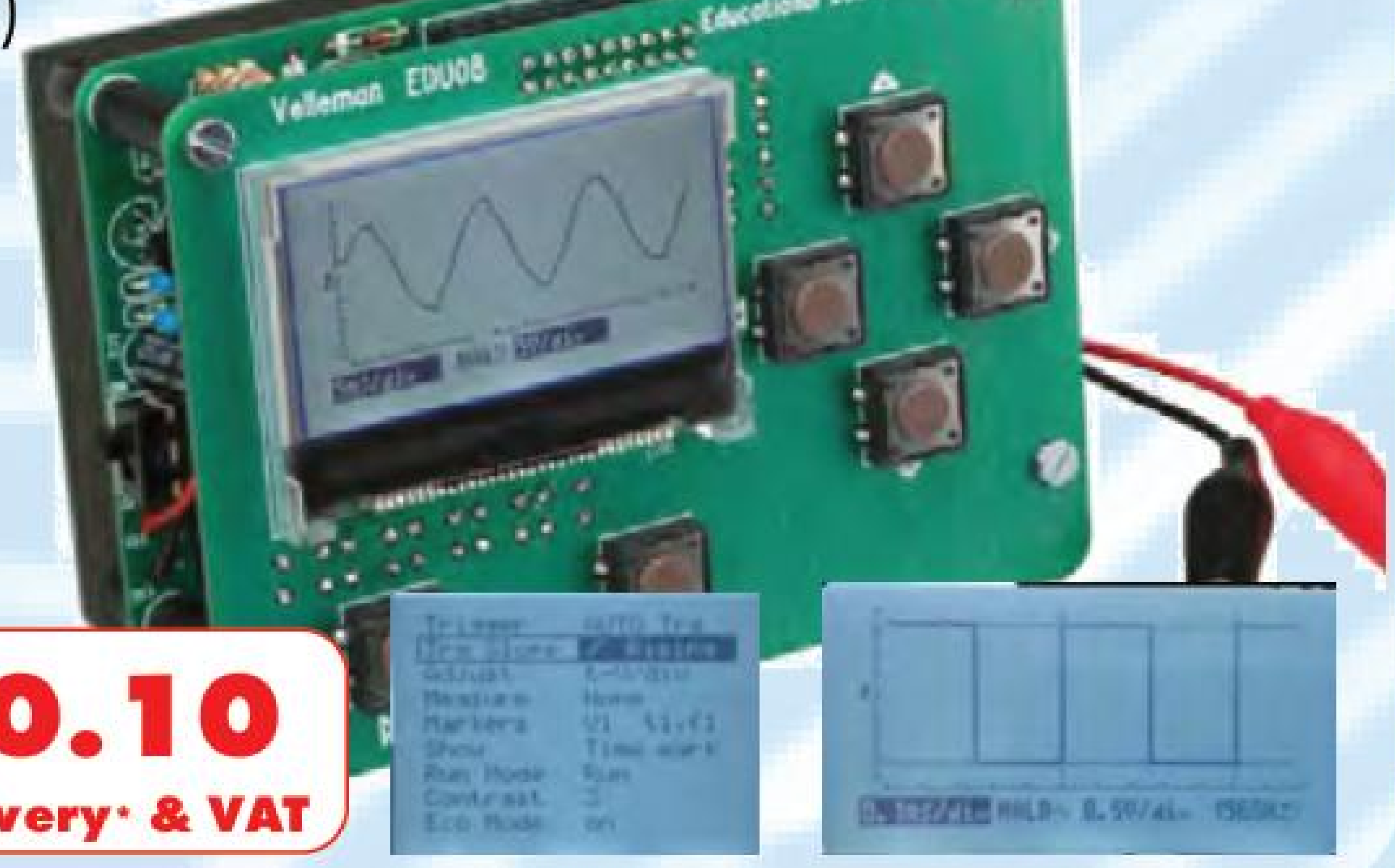
£99.90
Inc Delivery* & VAT

Build your own Oscilloscope

A new self assembly kit, ideal for education and way to visualise signals. Features: Markers, Frequency, dB, True RMS readouts
Timebase range:
10μs-500ms/division (15 steps)
Input sensitvity:
100mV-5V/division (6 steps)
Max Input voltage: 30Vpp
Max Sample Rate:
1ms/s repetitive signal,
100ks/s real time signal
Dim: 80 x 115 x 40mm

Quote: EPESCOPE

£50.10
Inc Delivery* & VAT


Velleman EDU08
Educational LCD Oscilloscope

ELECTRONIC COMPONENTS
www.esr.co.uk

10/15

Tel: 0191 2514363
Fax: 0191 2522296
sales@esr.co.uk

ESR Electronic Components Ltd
Station Road,
Cullercoats, Tyne &
Wear. NE30 4PQ

Prices **INCLUDE** Delivery* & VAT.
*Delivery to any UK Mainland address, please call for delivery options for Highland & Island, Northern Ireland, Ireland, Isle of Man, Isle of Wight & Channel Islands

VOL. 45 No. 02 FEBRUARY 2016

Editorial Offices:
EVERYDAY PRACTICAL ELECTRONICS
EDITORIAL Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299. **Fax:** 01202 843233.
Email: fay.kearn@wimborne.co.uk
Website: www.epemag.com
See notes on **Readers' Technical Enquiries** below – we regret technical enquiries cannot be answered over the telephone.

Advertisement Offices:
Everyday Practical Electronics Advertisements
113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU
Phone: 01202 880299 **Fax:** 01202 843233
Email: stewart.kearn@wimborne.co.uk

Editor: MATT PULZER
Subscriptions: MARILYN GOLDBERG
General Manager: FAY KEARN
Graphic Design: RYAN HAWKINS
Editorial/Admin: 01202 880299
Advertising and Business Manager: STEWART KEARN 01202 880299
On-line Editor: ALAN WINSTANLEY

Publisher: MIKE KENWARD

READERS' TECHNICAL ENQUIRIES
Email: fay.kearn@wimborne.co.uk
We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years' old. Letters requiring a personal reply must be accompanied by a stamped self-addressed envelope or a self-addressed envelope and international reply coupons. We are not able to answer technical queries on the phone.

PROJECTS AND CIRCUITS
All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it.

A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

COMPONENT SUPPLIES
We do not supply electronic components or kits for building the projects featured, these can be supplied by advertisers.

We advise readers to check that all parts are still available before commencing any project in a back-dated issue.

ADVERTISEMENTS
Although the proprietors and staff of EVERYDAY PRACTICAL ELECTRONICS take reasonable precautions to protect the interests of readers by ensuring as far as practicable that advertisements are bona fide, the magazine and its publishers cannot give any undertakings in respect of statements or claims made by advertisers, whether these advertisements are printed as part of the magazine, or in inserts.

The Publishers regret that under no circumstances will the magazine accept liability for non-receipt of goods ordered, or for late delivery, or for faults in manufacture.

TRANSMITTERS/BUGS/TELEPHONE EQUIPMENT
We advise readers that certain items of radio transmitting and telephone equipment which may be advertised in our pages cannot be legally used in the UK. Readers should check the law before buying any transmitting or telephone equipment, as a fine, confiscation of equipment and/or imprisonment can result from illegal use or ownership. The laws vary from country to country; readers should check local laws.

EVERYDAY PRACTICAL ELECTRONICS

Preferred numbers and the E series

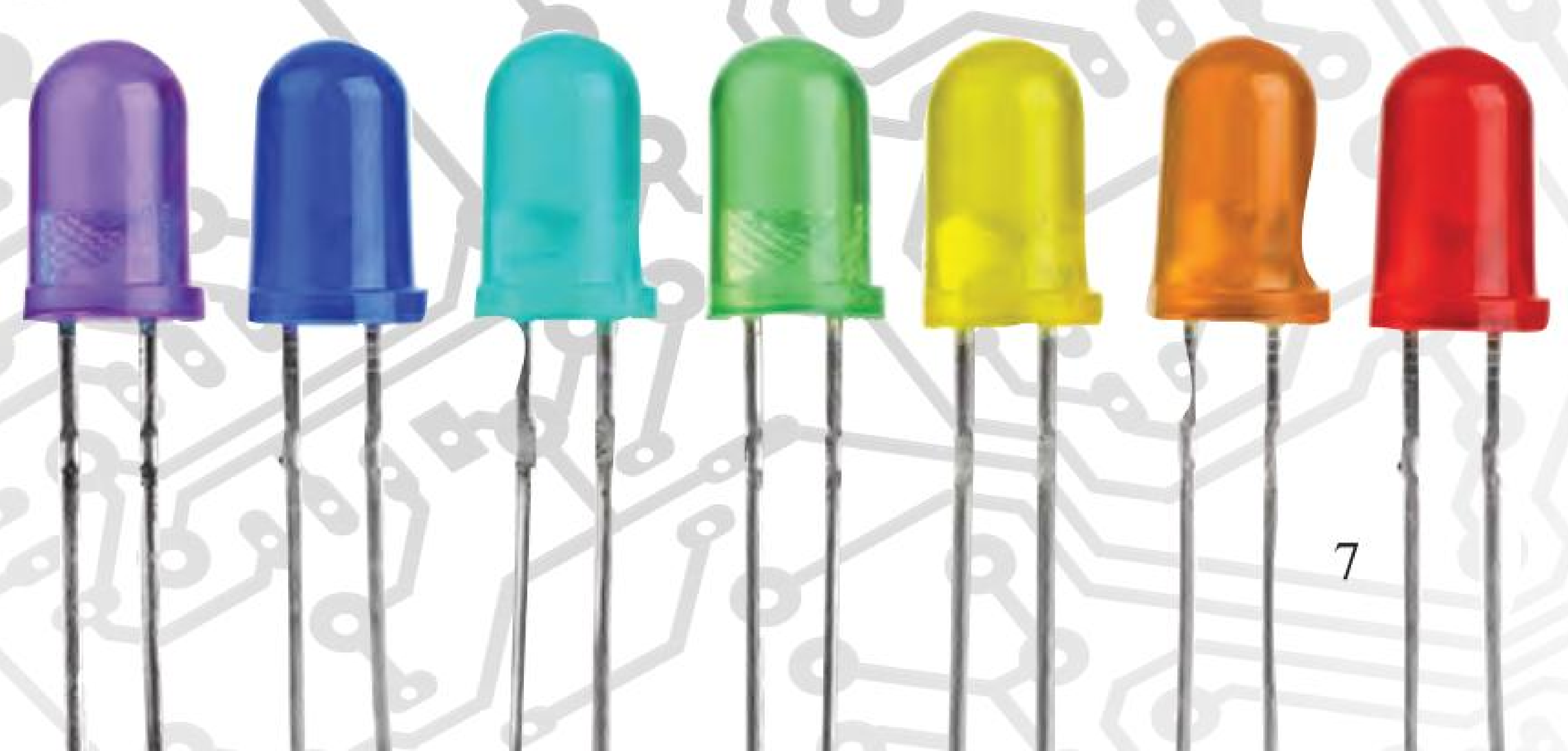
Reading through last month's *Audio Out* article and its many references to the common E series of components I decided to have a wider look at the origin and use of these handy numbers. For those of you with an interest in the history of industrial design, I recommend a visit to **https://en.wikipedia.org/wiki/Preferred_number**, where there is an excellent explanation of the many uses of 'preferred numbers'.

At first glance, the E12 range of resistor values looks rather arbitrary: 10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82. (The '12' in 'E12' signifies the number of values over an order of magnitude.) Why don't manufacturers simply make resistors in nice regular steps: 1kΩ, 2kΩ, 3kΩ, 4kΩ, 5kΩ, 6kΩ…? The answer can be summed up in one important word – 'tolerance'. The engineering term 'tolerance' refers to the accuracy of an item's key parameter(s). For the E12 series of resistors (or capacitors, inductors and zener diodes) it means the actual value is only guaranteed to be within 10% of the quoted value. So, in theory, an E12 1kΩ resistor could have an actual value of plus or minus 10% of 1000Ω = 100Ω. In other words it could have any value between 900Ω and 1100Ω; and without measuring its value you simply have no way of knowing where in this value spread it resides.

Given this spread, there is not much point in making an E12 1.1kΩ resistor because its value might be anywhere between 0.99kΩ and 1.21kΩ – a significant overlap with the 1kΩ resistor value spread. To avoid overlap, the next value up is 1.2kΩ, which has a spread from 1.08kΩ to 1.32kΩ. Now, there is a tiny overlap, but essentially the two quoted values of 1kΩ and 1.2kΩ are sufficiently far apart to definitely be almost always different values, but sufficiently close together to maximize the number of choices on offer to designers and manufacturers. You can repeat this simple mathematical analysis all the way up the E12 series and get similar results. Looking at the final value in the series, but the value one below 1kΩ, we reach 0.82kΩ, add 10% to that and you get 0.902kΩ, which together with the 1.1kΩ resistor neatly bracket the 1kΩ resistor's spread.

Exactly the same trick works with the widely used E24 (5%) series of resistor values and all the other series, such as the somewhat daunting E192 for 0.5% tolerance.

It is also worth remembering that tolerance is not just about a static value. Components such as resistors will drift with temperature and time, so even if you carefully match a pair of cheap resistors with a DVM, you cannot assume they will always operate in tandem. If you need close tolerance resistors in your design – for example, in an op amp difference amplifier, then it is usually best to start out with high tolerance components.



NEWS

A roundup of the latest Everyday News from the world of electronics

Dramatic rise in 4K/HDR TV power use – *report by Barry Fox*

The European Environment Bureau (EEB) based in Brussels, is warning that UHD 4K televisions use an average 30 per cent more energy than HD sets, and could lock unsuspecting owners into open-ended higher energy bills. The EEB warning stems from a 40-page report issued by the US Natural Resources Defense Council. The report also warns that TVs with an HDR (high dynamic range) picture, consume twice as much power as basic 4K sets – and some HDR sets may gobble ten times the peak power.

Says EEB spokesman Jack Hunter: 'TVs were already the energy hog among entertainment gadgets. Now bargain hunters know to keep an even closer eye on energy costs, not just price tags. It's clear some UHD models perform far better than others. Shoppers should use the EU energy label sold with all UK TVs to compare models and dodge energy monsters.'

The NRDC report, *The Big Picture: Ultra High-Definition Televisions Could Add $1 Billion to Viewers' Annual Electric Bills* notes that 'as the shift to UHD televisions is now in its early stages, there is still time for manufacturers to incorporate more efficient designs and components into all new models and prevent much of this potential additional electricity use and resultant pollution.'

Power analysis

The NRDC analysed a total of 21 televisions, roughly half instore and half in the laboratory, explaining: 'While we tested only a fraction of the models available on the market, we believe we covered a sufficiently large cross-section of 55-inch televisions to answer the research questions we posed'.

The NRDC found "dramatic differences in the power consumption among models of the same size, with the least-efficient model we tested using almost three-times more power during active operation than the most-efficient models".

'This indicates that the technology already exists to make energy-saving improvements to the most inefficient UHD televisions' the NRDC concludes.

'Some of the 4K televisions on the market today are capable of producing superior picture quality (eg, brighter whites, darker blacks, and superior contrast ratios) when they receive HDR content' says the NRDC. 'These televisions, generically referred to as 4K HDR or HDR-capable UHD TVs, are expected to be heavily promoted to, and sought by, consumers in the near future.'

Power consumption: HDR vs 4K

'The lesson from this testing is that HDR could have a bigger impact on television energy use than the jump to 4K by itself, particularly in combination with the other, optional UHD features and the continuing push for ever bigger screens. If the least-efficient design strategies for implementing 4K dominate sales and HDR becomes widespread, average 4K TV energy use could more than double from today's HD models. More testing is needed to determine if the very large power increase we observed is representative of the 4K HDR models entering the market.'

'High dynamic range (HDR) has only recently debuted in the television market' the NRDC explains. 'Debates continue within the industry over the amount of maximum luminance that televisions must contain in order to claim HDR compatibility. Some manufacturers are designing televisions with peak luminance levels of only 400 to 500 nits, but delivering black levels so low that the dynamic contrast (difference between brightest and darkest parts of the screen) is quite wide. Others have argued for a peak luminance capability of at least 700 to 1,000 nits, with forecasts of 1,200-to-1,500-nit capabilities on compatible models in the near future. Dolby Vision aspires to deliver a luminance range of 0 to 10,000 nits and has already shown a prototype capable of 4,000 nits, roughly 10 to 13-times brighter than a typical HD TV.'

Movie tests

'As no information was available about the potential energy impact of playing HDR content on these models, we tested two movies (*Maze Runner* and *Exodus: Gods and Kings*) on the Samsung UHD TV model UN55JS9000, first with the 4K version of content and then with the 4K HDR-encoded edition. On average, the HDR version of the movie caused this television to use 47 per cent more energy than the non-HDR version. Even though the power use of the two versions was similar for very dark scenes, it was dramatically higher (often double) on extremely bright scenes.'

Exodus: Gods and Kings averaged 106.9W without HDR and 149.3W with HDR – a 40 per cent increase. *Maze Runner* averaged 92.2W without HDR and 145.4W with HDR – a 54 per cent increase. The NRDC concluded:

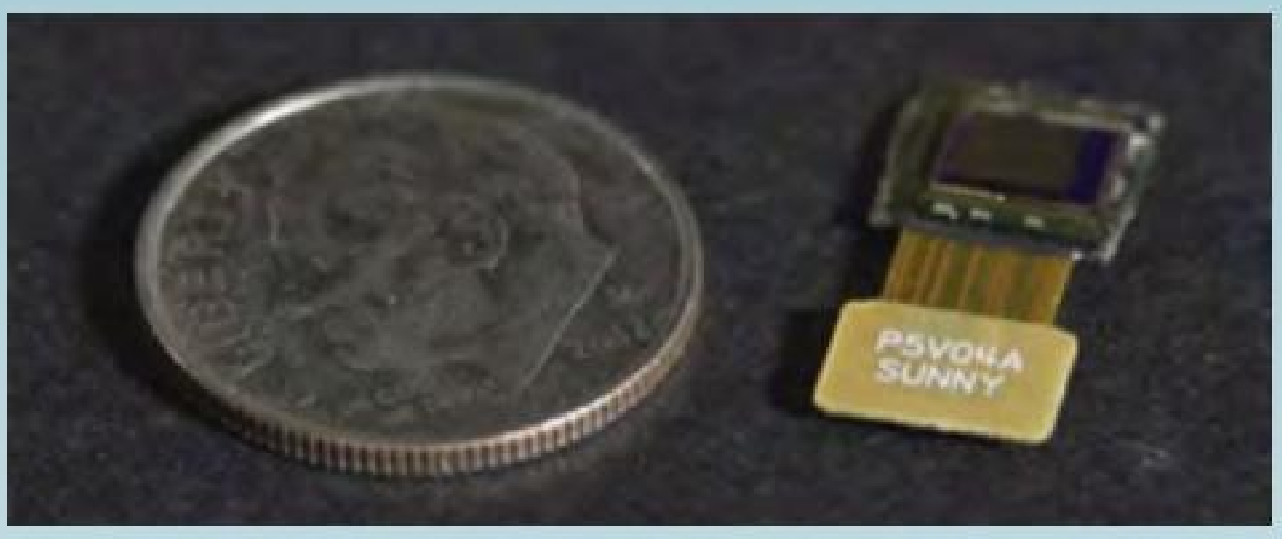
1) HDR has the potential to be the most energy consumptive of all the aspects of 4K televisions we have tested so far, particularly as HDR-encoded content proliferates.

Continued on page 9

Ultra-thin no-lens 'FlatCam'

How thin can a camera be? 'Very', say Rice University researchers in the US, who have developed patented prototypes of their technological breakthrough. Their device is is little more than a thin sensor chip with a mask that replaces lenses in a traditional camera. Making it practical are sophisticated computer algorithms that process what the sensor detects and converts the sensor measurements into images and videos.

Traditional cameras are shrinking, driven by their widespread adoption in smartphones. But they all require lenses – and the post-fabrication assembly required to integrate lenses into cameras raises their cost. FlatCam does away with those issues in a camera that is also thin and flexible enough for applications that traditional devices cannot serve. They could be fabricated like microchips, with the precision, speed and the associated reduction in costs – plus, doing away with lenses made the most recent prototype thinner than a dime.



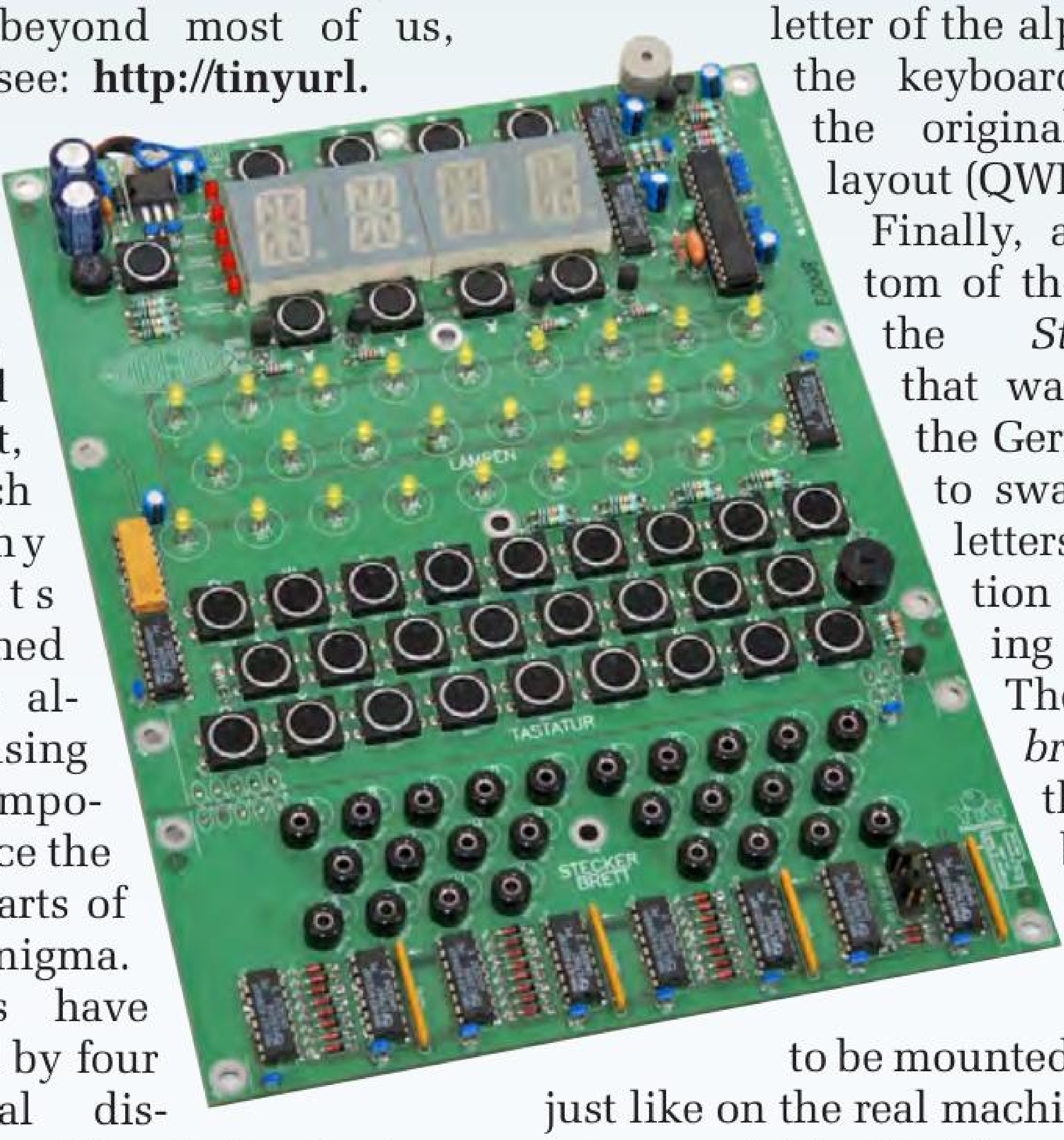
The dime on the left is approximately the size of a 5p coin

FlatCam shares its heritage with lens-less pinhole cameras, but instead of a single hole, it features a grid-like coded mask positioned very close to the sensor. Each aperture allows a slightly different set of light data to reach the sensor. Raw data sent to the back-end processor – for now, a desktop computer – is sorted into an image. Like much larger 'light field cameras', the picture can be focused to different depths after the data is collected.

Rice's hand-built prototypes use off-the-shelf sensors and produce 512-by-512 pixel images in seconds, but the researchers expect that resolution will improve as more advanced manufacturing techniques and reconstruction algorithms are developed.

Electronic Enigma kit

Alan Turing, Bletchley Park and the cracking of Enigma are the key elements of a glorious piece of British electronics history that continues to grip our imagination. Buying or building your own electro-mechanical German Enigma machine is beyond most of us, although do see: **http://tinyurl.com/37natep**



So, rather than building an Enigma replica, which would be difficult, some Dutch cryptography enthusiasts have designed an electronic alternative, using modern components to replace the mechanical parts of the original Enigma.

The wheels have been replaced by four alphanumerical displays, each capable of displaying the entire alphabet. Above and below the displays are up and down buttons allowing the initial settings to be changed. Just below the displays are 26 LEDs, replacing the 26 lamps of the original machine. Each LED represents one letter of the alphabet. Below the lamp section is the keyboard, with 26 push-buttons. Again, each button represents one letter of the alphabet and the keyboard features the original German layout (QWERTZ).

Finally, at the bottom of the PCB lies the *Steckerbrett*, that was used by the German Army to swap pairs of letters, in addition to the coding wheels. The *Steckerbrett*-part of the PCB can be separated from the rest to allow it to be mounted vertically, just like on the real machine.

Appropriately, the kit can be bought (for £150) from the Bletchley Park Trust shop: **www.bletchleypark.org.uk/shop**

4K/HDR TV power... continued

2) In most of the televisions that they measured, the background power consumption of everything except light production is about 40 to 60W. But total power consumption can rise by a factor of three to five from there, depending on how much of the screen is lit and how brightly. HDR TVs capable of 1,000 nits (or more) peak luminance could raise total peak power consumption by a factor of 6 to 10 from the television's background power consumption, to a maximum of roughly 350 to 500W for 55-inch models.

'Continued improvements in LED efficiency will help to mitigate this effect', the NRDC predicts. But it seems clear that viewers will still be paying more in electricity to watch with HDR.

3D printing waveguides

The UK's National Physical Laboratory (NPL) and Imperial College London are investigating the design, fabrication and testing of waveguides manufactured using 3D-printing techniques, by providing the underpinning metrology needed to determine their electromagnetic performance.

Metallic rectangular waveguides (or waveguides, for short) are used to carry electromagnetic waves from point to point due to their relatively low-loss characteristics. They are used in many microwave applications, including radar, communications, astronomy and space. However, they can be difficult to manufacture with the precision that's needed using conventional machining techniques.

Commercial waveguides are traditionally manufactured by reshaping metal pipes through rectangular dies, or milling or erosion machining techniques, which are relatively expensive technologies. The current manufacturing cost for complex 3D structures limits potential low-cost applications; this is exacerbated in the microwave and millimetre-wave bands due to the higher precision needed for the smaller features at these shorter wavelengths.

3D-printing technology is particularly attractive for manufacturing waveguides as it allows components and circuits used at microwave and millimetre-wave frequencies to be manufactured cheaply while retaining good overall electrical performance. Since the concept of using waveguide dates back more than 100 years, this is essentially a 19th century technology fabricated using 21st century techniques.

microchip DIRECT

microchipDIRECT
Memory Programming
We Can Now Program Memory Devices
BUY DIRECT
at
microchipDIRECT.com

microchipDIRECT offers access to the world's largest inventory of Microchip products and the most comprehensive online resource for pricing and support directly from Microchip Technology. We invite you as a valued Microchip customer to experience our service 24 hours a day, 7 days per week.

Visit www.microchipDIRECT.com and enjoy the confidence and convenience of buying from microchipDIRECT and take advantage of the following features:

- Direct stock from factory
- Direct customer service
- Secure ordering
- Volume pricing
- Credit lines
- Long-term orders and scheduling
- Programming and value add services
- Ability to adjust open orders
- Ship to your sites globally
- Online order status and notifications

microchip DIRECT
www.microchipdirect.com

MICROCHIP

www.microchipDIRECT.com

The Microchip name and logo, the Microchip logo are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners.
© 2015 Microchip Technology Inc. All rights reserved. DS40001752B. MEC2010Eng04/15

SPARK ENERGY METER

Part 1: Design by Dr Hugo Holden

This meter closely estimates the energy delivered to actual sparks in the ignition system under test, either a CDI or MDI system.

00.0
mJ
SPARK ENERGY METER
POWER
HIGH RANGE

A great way to measure the output of an ignition system is to load it with a high voltage bidirectional zener diode which approximates the actual voltage drop when a spark is established. Our meter uses a 1500V device, as explained below.

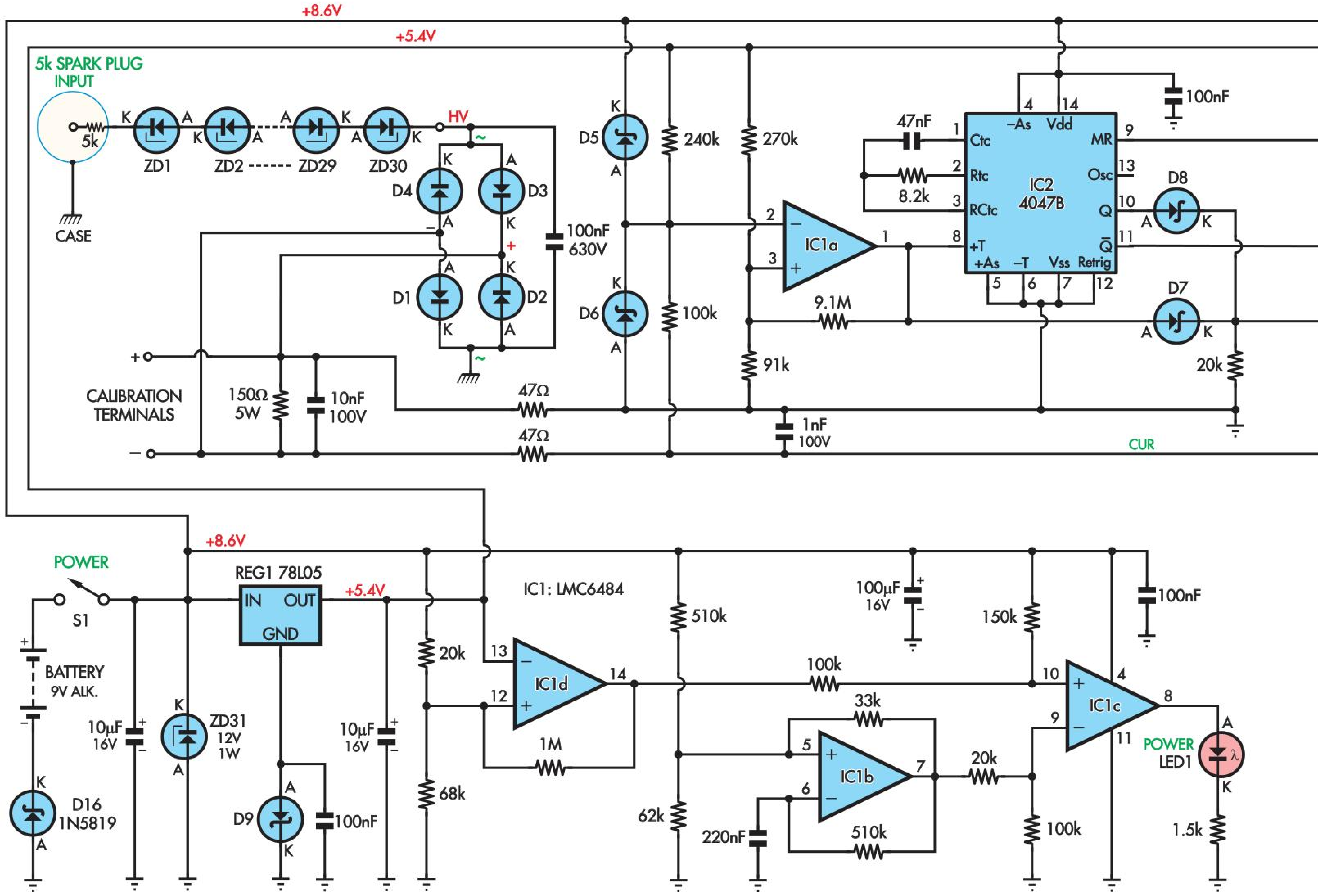
The meter has two ranges which are selected automatically, zero to 100mJ (millijoules) or zero to 1000mJ and it can work with a spark repetition rate up to 700 sparks per second (corresponding to more than 10000 RPM in a V8 engine) or down to just 1Hz. It can measure uni-polar or bi-polar spark voltages.

The meter is portable and battery-powered. It also has a low-battery indicator. It can be connected to a working engine one spark plug at a time or alternatively, it can be used to bench test an ignition system. Last, it works with single or double-ended ignition coils.

Circuit description

Fig.1 shows the complete circuit. The HT connection from the ignition system is applied to a spark plug, which is a 5kΩ resistor type, BR8HS. The plug's earth part of the electrode is cut off and the plug is used as a feed through connector.

The 5kΩ resistor in the plug helps to limit and isolate very brief high current transients caused by the stray and distributed capacitance of the ignition coil, distributor and the wiring.


+8.6V
+5.4V
5k SPARK PLUG INPUT
5k
CASE
K
A
ZD1
ZD2
ZD29
ZD30
HV
~
D4
D3
D1
D2
100nF 630V
D5
D6
240k
100k
270k
91k
IC1a
9.1M
47nF
8.2k
IC2 4047B
Ctc
Rtc
RCtc
+T
+As
−T
Vss
Retrig
−As
Vdd
MR
Osc
Q
Q̄
100nF
D8
D7
20k
CUR
CALIBRATION TERMINALS
150Ω 5W
10nF 100V
47Ω
47Ω
1nF 100V
POWER
S1
BATTERY 9V ALK.
D16 1N5819
10µF 16V
ZD31 12V 1W
REG1 78L05
IN
OUT
GND
D9
100nF
10µF 16V
20k
68k
IC1: LMC6484
IC1d
1M
510k
62k
100µF 16V
100k
33k
IC1b
220nF
510k
150k
100nF
IC1c
20k
100k
POWER LED1
1.5k

SPARK ENERGY METER

Fig.1: full circuit of the *Spark Energy Meter*. ZD1-ZD30 are the 1.5kVdummy load. The resulting voltage is rectified by bridge D1-D4 and passes through a 150Ω 5W shunt resistor. The output is integrated by IC3b, while a sample-and-hold buffer comprising IC5b-IC5d and IC3c provide a steady signal for the LCD meter. Q1 discharges the hold capacitor if the spark train ceases, while IC3d and IC4a switch the unit to a higher range for more energetic sparks. IC1b-IC1d monitor the battery voltage and flash LED1 if it's low.

The high voltage signal from the plug is fed to a string of 30 100V 5W zener diodes, wired to create a high-voltage, high-power bidirectional 1500V zener diode.

We found that an effective or equivalent spark sustaining voltage of 1500V meant that signal processing of the 'dwell artefact' is avoided when testing ignition coils directly.

After passing through the bidirectional zener diode assembly, the signal is fed to a bridge rectifier (diodes D1 to D4) with a 100nF capacitor across it, to suppress short-term variations in voltage. Its output goes to a 150Ω 5W current-sense resistor shunted by a 10nF capacitor to provide further filtering.

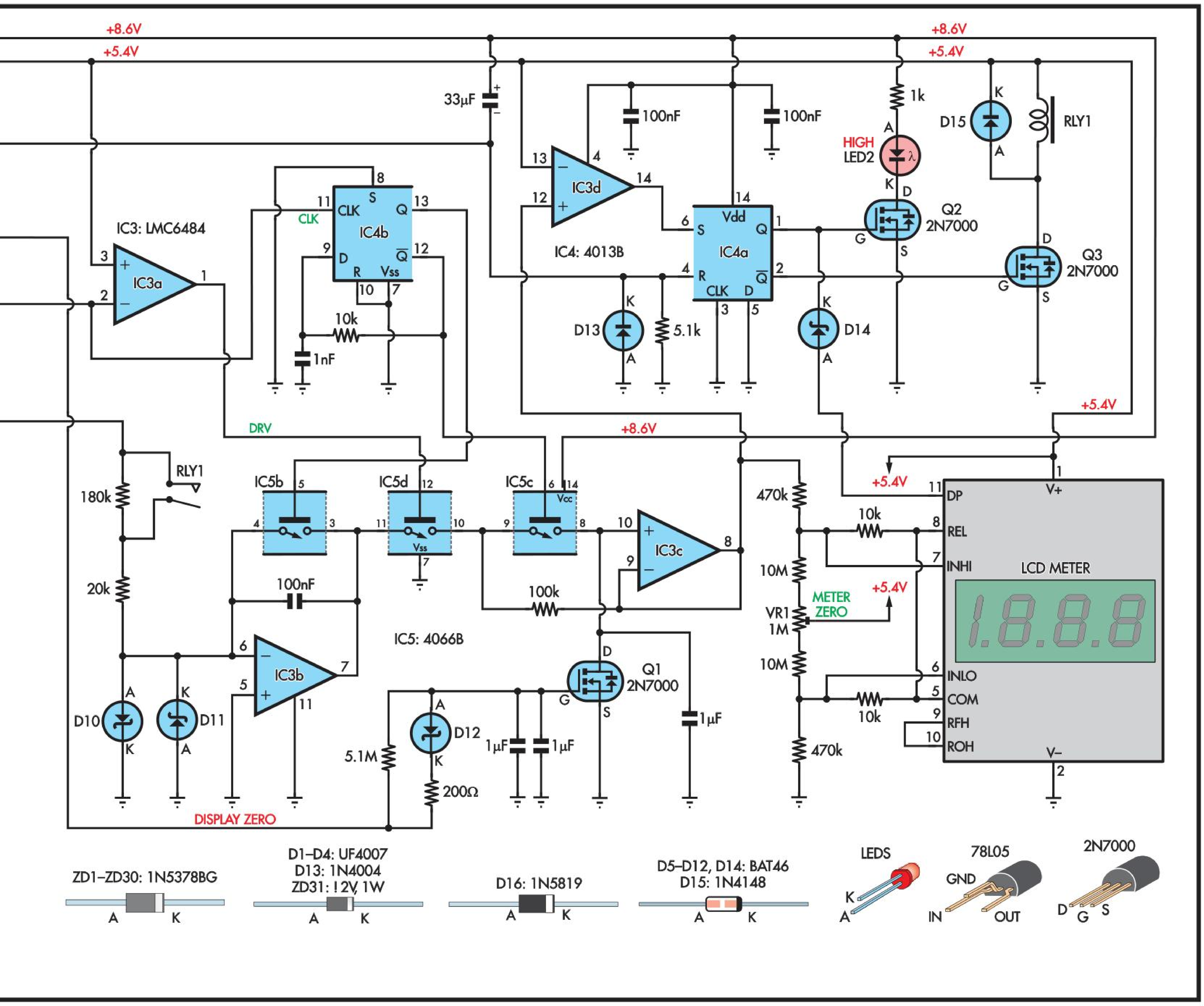
These capacitors barely affect the signal's waveform or integrated value.

The voltage across the 150Ω 5W resistor is proportional to the spark current. This resistor's top end is connected to circuit ground via a 47Ω resistor; the negative end goes to the inverting input of op amp IC3b via an RC low-pass filter (47Ω and 1nF) and a series-connected pair of resistors (180kΩ + 20kΩ).

IC3b operates as the integrator at the heart of this circuit. To measure the

Specifications

Range:	0-100mJ (low range), 0-1000mJ (high range, automatic switching)
Input:	standard spark plug connection with separate earthing lead
Measurement linearity:	~4%
Power supply:	9V alkaline battery (internal), ~17mA drain
Low-voltage indication:	power LED flashes below ~7.2V
Calibration:	onboard display zeroing and scale adjustment. (Scale is set accurately using a calibrator board, described below.)


+8.6V
+5.4V
33µF
100nF
100nF
1k
HIGH
LED2
D15
RLY1
IC3: LMC6484
IC3a
IC3d
IC4b
CLK
IC4: 4013B
IC4a
Q2
2N7000
Q3
2N7000
D13
5.1k
D14
10k
1nF
DRV
RLY1
180k
20k
IC5b
IC5d
IC5c
IC3c
470k
10M
VR1
1M
METER
ZERO
10M
470k
LCD METER
DP
REL
INHI
INLO
COM
RFH
ROH
V+
V–
100nF
100k
IC5: 4066B
IC3b
Q1
2N7000
1µF
D10
D11
D12
5.1M
200Ω
1µF
1µF
10k
10k
DISPLAY ZERO
ZD1–ZD30: 1N5378BG
D1–D4: UF4007
D13: 1N4004
ZD31: 12V, 1W
D16: 1N5819
D5–D12, D14: BAT46
D15: 1N4148
LEDS
78L05
GND
IN
OUT
2N7000
D G S
A K

energy of the spark, we need to calculate the product of the voltage across the dummy load (fixed at 1500V) with the integral of load current over time. Another way to think of this integral is the area under a curve plotting current against time. Luckily, a simple op amp integrator performs this calculation for us.

IC3b uses a 100nF integrator capacitor which is reset to 0V before each spark and charges at a rate proportional to spark current. The voltage across the 150Ω resistor is Ispk × 150. Ignoring the 180kΩ series resistor (which is initially shorted out by reed relay RLY1), the combination of a 20kΩ resistor and 100nF capacitor gives an output at pin 7 of Ispk × 150 ÷ (20kΩ × 100nF) = 75000V/A.s or 75V/mA.s. Given the constant 1500V load voltage, this is equivalent to 50V/J (75000V / 1500V; 1J = 1V.A.s).

Thus, the maximum output we can expect from rail-to-rail op amp IC3b running from a 9V battery is around 5V, representing 100mJ.

To take higher readings, RLY1 switches off (as explained later) and this increases the source resistance of IC3b from 20kΩ to 200kΩ, reducing its sensitivity to 5V/J and thus readings up to 1J are possible.

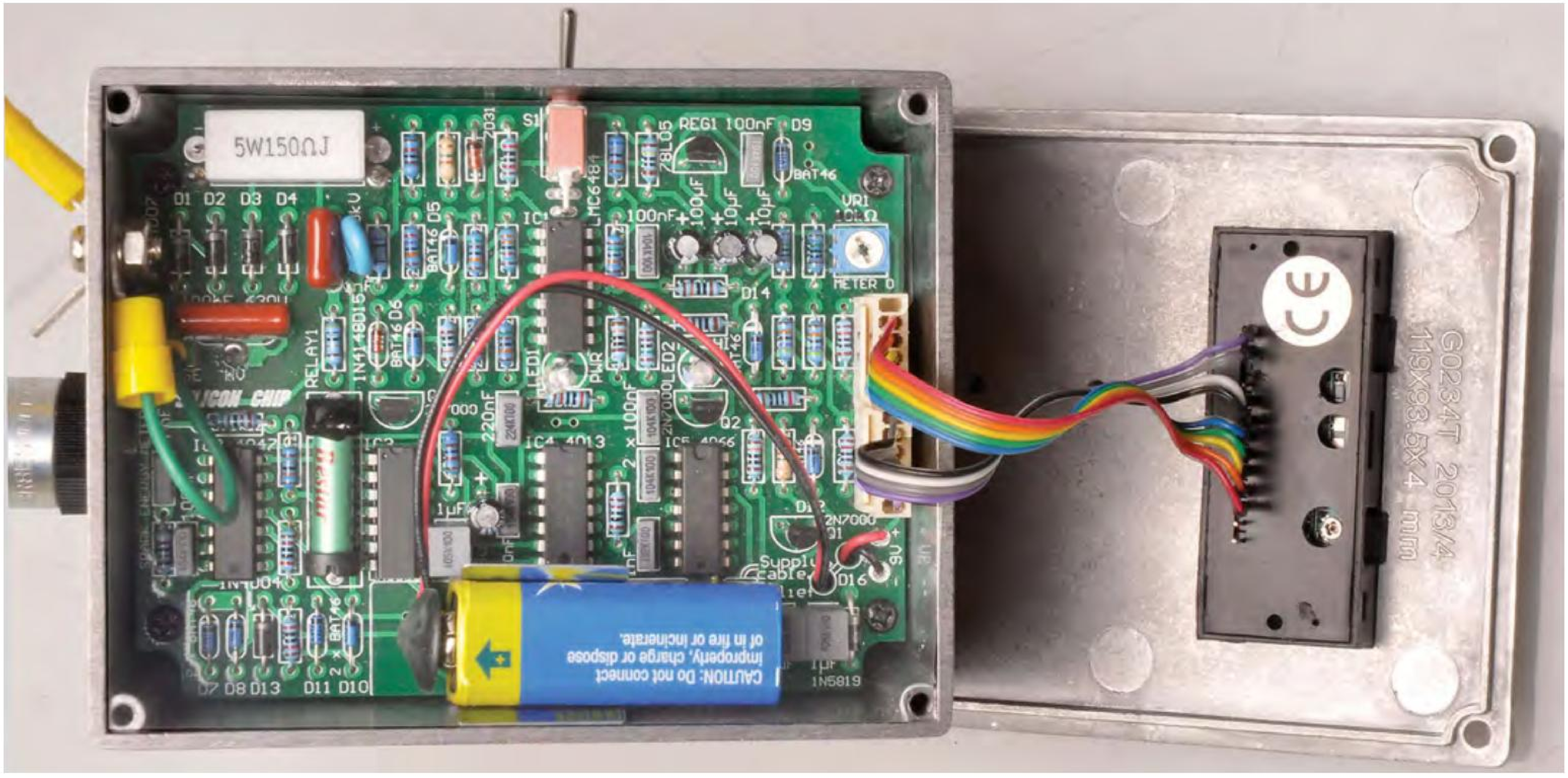
Note that because the shunt voltage is applied to a bridge rectifier before being fed to IC3b, both positive and negative spark voltages contribute to the reading.

Sample and hold

Because the spark duration is quite short, but we want a steady reading on the display, the circuit incorporates sample and hold. The energy of every second spark is measured and once the reading is complete, it is 'latched' in the hold buffer as soon as the next spark is detected, resulting in a steady reading on the LCD panel meter (assuming the spark energy is relatively consistent).

Op amp stage IC1a is used to detect the start of each spark. Its non-inverting input, pin 3, has a reference voltage of 1.35V applied, generated by the 270kΩ/91kΩ resistive divider across the 5.4V regulated supply rail. The inverting input, pin 3 normally sits at around 1.6V due to the 240kΩ/100kΩ divider between the 5.4V rail and the bottom of the sense resistor, which is at ground potential between sparks.

When a spark occurs, once the current rises above about 3mA, this



Just a little smaller than life-size, this inside shot shows how the PCB fits inside the diecast case, with the display mounted on the lid At left, just in view, is the base of the spark plug used as a termination point, along with the earth connection and double lug. Construction details will be provided in the second part of this project, next month.

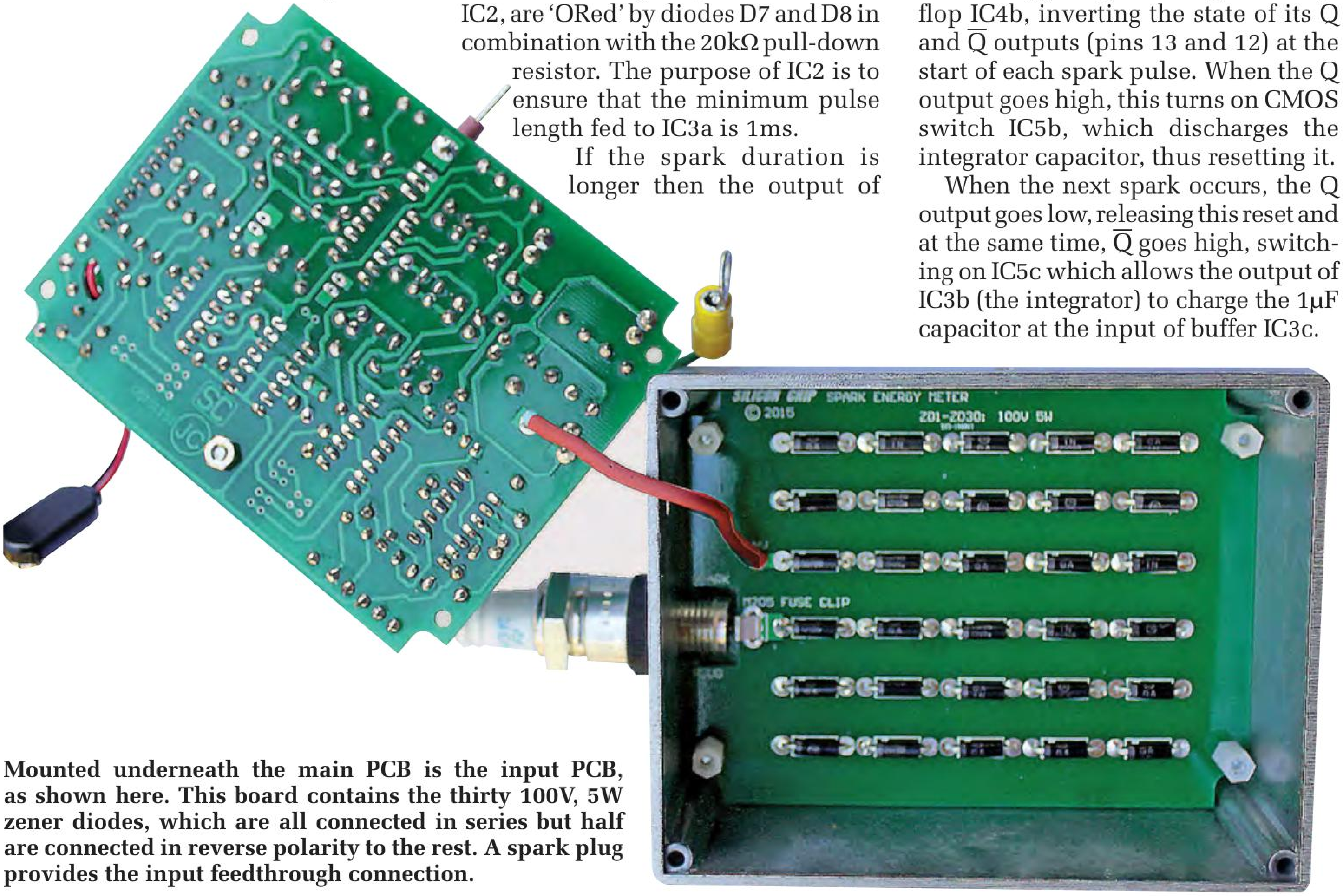
causes a voltage of 0.45V across the sense resistor and thus the voltage at pin 2 of IC1a drops below 1.3V, causing the output of IC1a to swing high. The 9.1MΩ feedback resistor provides a small amount of hysteresis to prevent output oscillation. IC1a then triggers monostable IC2 which produces a 1ms output pulse at Q (pin 10).

These two signals, from IC1a and IC2, are 'ORed' by diodes D7 and D8 in combination with the 20kΩ pull-down resistor. The purpose of IC2 is to ensure that the minimum pulse length fed to IC3a is 1ms.

If the spark duration is longer then the output of IC1a will still be high while the output of IC2 is low, but if the spark is less than 1ms, IC2 keeps the trigger signal high for that minimum period.

This trigger signal then goes to flip-flop IC4b, inverting the state of its Q and $\overline{Q}$ outputs (pins 13 and 12) at the start of each spark pulse. When the Q output goes high, this turns on CMOS switch IC5b, which discharges the integrator capacitor, thus resetting it.

When the next spark occurs, the Q output goes low, releasing this reset and at the same time, $\overline{Q}$ goes high, switching on IC5c which allows the output of IC3b (the integrator) to charge the 1µF capacitor at the input of buffer IC3c.



Mounted underneath the main PCB is the input PCB, as shown here. This board contains the thirty 100V, 5W zener diodes, which are all connected in series but half are connected in reverse polarity to the rest. A spark plug provides the input feedthrough connection.

Spark Energy Meter: Parts List

1 double-sided PCB available from the *EPE PCB Service*, code 05101151, 110.5 × 85mm
1 double-sided PCB available from the *EPE PCB Service*, code 05101152, 110.5 × 85mm
1 front panel label 109 × 84mm
1 diecast box 119 × 94 × 57mm
1 LCD panel meter
1 5V reed relay (RELAY1)
1 SPDT PCB mount toggle switch (S1)
1 resistive spark plug 14mm thread and preferably 12.7mm reach or similar (BR8HS)
1 9V U clip battery holder
1 9V battery snap and lead
1 9V alkaline battery
1 TOP-3 silicone washer
2 6-way polarised headers with 2.54mm spacings
2 6-way header plugs with 2.54mm spacings
8 stick-on rubber feet
1 alligator clip
1 M4 × 10mm screw
1 M4 nut
1 4mm star washer
1 crimp eyelet (1mm diameter cable entry)
1 6.3mm chassis spade connector
1 6.3mm crimp female spade connector (1mm diameter cable entry)
1 M3 × 6mm countersunk screw
1 M3 nut
4 M3 × 12mm countersunk screws
8 M3 tapped nylon spacers
4 M3 × 5mm machine screws
1 100mm length of 9-way rainbow cable
1 200mm length of 7.5A mains-rated cable
1 1m length of 7.5A green or black mains rated cable
1 200mm length of 4mm diameter heatshrink tubing
1 M205 fuse clip
2 PC stakes
1 1MΩ horizontal trimpot (VR1)

Semiconductors
2 quad CMOS op amps (IC1, IC3)
1 4047B monostable/astable multivibrator (IC2)
1 4013B dual D flip-flop (IC4)
1 4066B quad CMOS switch (IC5)
1 78L05 low power 5V regulator
3 2N7000 N channel FETs (Q1-Q3)
30 1N5378BG 100V 5W Zener diodes (ZD1-ZD30)
1 12V 1W Zener diode (ZD31)
4 UF4007 1A 1000V fast diodes (D1-D4)
9 BAT46 Schottky diodes (D5-D12, D14)
1 1N4004 1A diode (D13)
1 1N4148 switching diode (D15)
1 1N5819 1A Schottky diode (D16)
2 3mm LEDs (LED1,LED2)

Capacitors
1 100μF 16V electrolytic
1 33μF 16V electrolytic
2 10μF 16V electrolytic
3 1μF MKT
1 220nF MKT
6 100nF MKT
1 100nF 630V polyester (greencap)
1 47nF MKT
1 10nF 630V polyester (greencap) or 3kV ceramic
1 1nF 1kV ceramic
1 1nF MKT

Resistors (0.25W, 1%)
2 10MΩ
1 9.1MΩ
1 5.1MΩ
1 1MΩ
2 510kΩ
2 470kΩ
1 270kΩ
1 68kΩ
1 62kΩ
1 33kΩ
4 20kΩ
3 10kΩ
1 8.2kΩ
1 5.1kΩ
1 240kΩ
1 180kΩ
1 150kΩ
4 100kΩ
1 91kΩ
1 1.5kΩ
1 1kΩ
1 200Ω
1 150Ω 5W
2 47Ω

Parts List For Calibrator

1 PCB available from the *EPE PCB Service*, code 05101153, 47 × 61mm
2 2-way screw terminals with 5.08mm spacings
1 25mm length of 0.7mm tinned copper wire
3 PC stakes
1 100Ω horizontal trimpot (VR1)
1 50kΩ horizontal trimpot (VR2)

Semiconductors
1 7555 CMOS timer (IC1)
1 LM317T adjustable 3-terminal regulator (REG1)
1 IRF540 N-channel MOSFET (Q1)
1 BC337 NPN transistor (Q2)
1 BC327 PNP transistor (Q3)
2 1N4004 1A diodes (D2)

Capacitors
1 100μF 16V electrolytic
2 10μF 16V electrolytic
1 100nF MKT
1 10nF MKT

Resistors (0.25W, 1%)
1 220kΩ
1 240Ω
1 100Ω
1 10Ω

Alternative PWM circuit

2 1N4148 diodes (D3,D4)
1 1kΩ resistor in place of 220kΩ
1 250kΩ horizontal trimpot (VR2)

Reproduced by arrangement
with SILICON CHIP
magazine 2016.
www.siliconchip.com.au

However, note that CMOS switch IC5d must also be enabled for this capacitor to charge, and that is driven by op amp stage IC3a, configured as an inverter to invert the pulses from IC2. Hence, the sample-and-hold buffer only samples the output of the integrator after the spark duration and thus the integration of the spark current has been completed.

The 100kΩ resistor from the output of buffer IC3c to pin 9 of IC5c prevents leakage current through IC5c from slowly discharging the 1μF capacitor.

The output of IC3c therefore is a steady voltage representing the last energy value computed by the integrator and this is fed to the LCD panel meter via a resistive divider network with VR1 providing a zeroing adjustment.

The resistors chosen set the correct full-scale reading for the meter, so that with 5V at the output of IC3c, it will read either 100.0 (at 100mJ full-scale mode) or 1000 (at 1J full-scale mode).

Auto-ranging

As we mentioned earlier, reed relay RLY1 is initially switched on to provide the more sensitive 100mJ full-scale reading. Op amp IC3d is wired to compare the output of sample-and-hold buffer IC3c's output to the 5.4V rail.

Thus, once the reading goes above 108mJ, its output goes high, setting flipflop IC4a. IC4a is initially reset by the 33µF capacitor and 5.1kΩ resistor at its pin 4 input, with D13 discharging the capacitor at switch-off (this same signal also resets IC2 initially).

With IC4a reset, its Q output at pin 1 is low and thus Q2 is off, so the high-range indicator LED (LED2) is also off. At the same time, the $\overline{Q}$ output at pin 2 is high, so Q3 is switched on and this powers the coil of RLY1.

When the output of IC3d goes high and the flip-flop is set, LED2 switches on and RLY1 switches off. The only way to return to the higher-sensitivity 100mJ scale mode is to switch the unit off and on again, resetting IC4a.

Display zeroing

Ideally, when sparks are no longer being delivered to the unit, the display shouldn't just hold the last reading forever. We want it to drop to zero so we realise that there are no more sparks being detected (and thus no energy being measured). This is achieved by MOSFET Q1, which discharges the 1µF hold capacitor after a few seconds without any spark pulses.

The $\overline{Q}$ output of IC2 goes low for 1ms on every second spark detected, discharging the two 1µF capacitors at Q1's gate and thus keeping it off. However, if the sparks stop for long enough, these capacitors charge via the 5.1MΩ resistor and thus Q1 switches on, zeroing the reading.

Power supply

The unit is powered from a single 9V alkaline battery. Reverse polarity protection is provided by Schottky diode D16, while power switch S1 turns the unit on and off. 78L05 regulator REG1 has a Schottky diode in its ground leg to 'jack up' its output to 5.4V. This is to ensure that it's always above the output of IC3c, even with the meter at its maximum reading of 100mJ/1J, which corresponds to 5V.

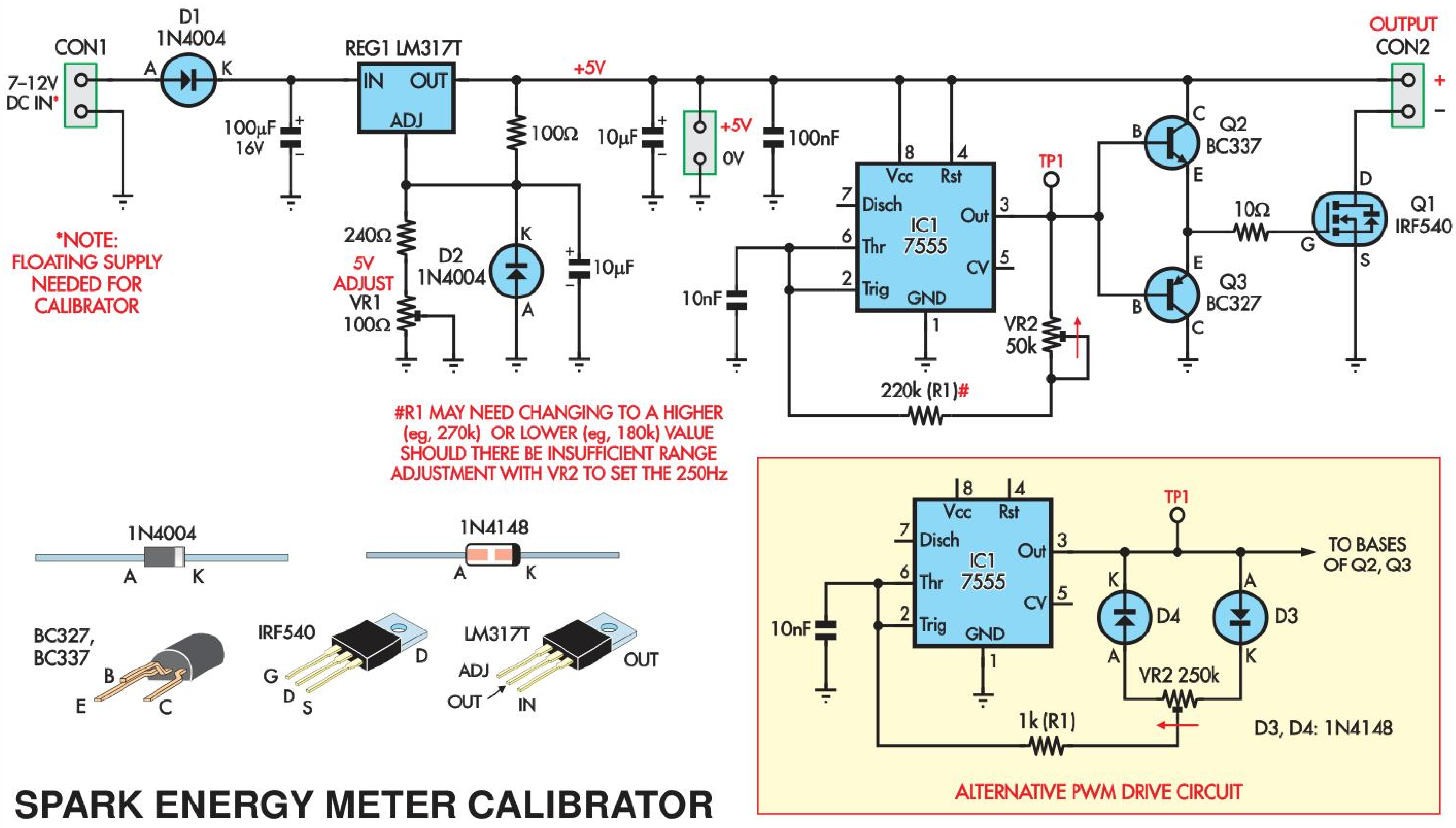
Op amp stages IC1b-IC1d provide a low-battery warning, which flashes power indicator LED1 if the battery voltage drops below 7.2V. IC1d is the low-battery comparator, with its inverting input (pin 13) connected to the 5.4V rail as a reference and pin 12 connected to a voltage divider across the battery. A 1MΩ positive feedback resistor provides hysteresis.

If the battery level is low, the output of IC1d goes low, reducing the voltage at input pin 10 of IC1c. This op amp acts as an OR-gate, so while the battery voltage is above the 7.2V threshold, its output is always high and thus power LED1 is lit constantly.

But once the voltage at pin 10 drops, astable oscillator IC1b drives its pin 9 input and causes the output to pulse, flashing LED1. The 510kΩ and 220nF component values at IC1b's inverting input (pin 6) in combination with the resistors connected to its pin 5 non-inverting input set the flash rate to around 2Hz with a duty cycle of around 75%.

Calibrator circuit

The meter must be calibrated before use to ensure accuracy and this is done by by applying a test signal with a repetitive 2ms –5V pulse across the 150W 5W resistor. The display is then


CON1
7–12V DC IN*
D1 1N4004
A K
REG1 LM317T
IN OUT
ADJ
+5V
100µF 16V
100Ω
10µF
+5V
0V
100nF
240Ω
5V ADJUST VR1 100Ω
D2 1N4004
K A
10µF
*NOTE: FLOATING SUPPLY NEEDED FOR CALIBRATOR
8 4
Vcc Rst
7 Disch
IC1 7555
6 Thr
Out 3
CV 5
2 Trig
GND
1
10nF
TP1
VR2 50k
220k (R1)#
#R1 MAY NEED CHANGING TO A HIGHER (eg, 270k) OR LOWER (eg, 180k) VALUE SHOULD THERE BE INSUFFICIENT RANGE ADJUSTMENT WITH VR2 TO SET THE 250Hz
B C E
Q2 BC337
Q3 BC327
10Ω
G D S
Q1 IRF540
OUTPUT CON2
+ –
1N4004
A K
1N4148
A K
BC327, BC337
B E C
IRF540
G D S
LM317T
ADJ OUT IN
TP1
K A
D4 D3
A K
VR2 250k
1k (R1)
TO BASES OF Q2, Q3
D3, D4: 1N4148
ALTERNATIVE PWM DRIVE CIRCUIT

SPARK ENERGY METER CALIBRATOR

Fig.2: the calibrator circuit. REG1 is adjusted to give a 5V output while VR2 allows the output frequency of IC1 to be set to 250Hz. This gives the required 2ms –5V pulses at CON2. With some small changes shown in the yellow box, the circuit can be used as a 1A, 5V/12V PWM motor speed controller or lamp dimmer instead.

calibrated to show 100mJ. This is done by adjusting the internal trimmer on the LCD. We've designed a PCB to perform this task and the circuit is shown in Fig.2. Once you've finished using it to calibrate the *Spark Energy Meter*, it can be reconfigured to operate as a pulse-width modulated (PWM) DC speed controller.

Since a 2ms pulse is required, the simple solution is to generate a 250Hz square wave with the required amplitude. If the duty cycle is close to 50%, the frequency and voltage can be adjusted to the correct values using measurements from a DMM.

The circuit operates from a 7-12V supply with reverse polarity protection by diode D1. REG1 is an adjustable regulator that is adjusted to give exactly 5V. Typically, the voltage between the OUT and ADJ terminal is 1.25V, but could range between 1.2 and 1.3V depending on the particular regulator.

The 100Ω resistor between the output and adjust terminal sets a nominal 12.5mA flowing through the 240Ω resistor and 100Ω trimpot. That current will allow the adjust terminal to be set to sufficient voltage for 5V at the output.

CMOS timer IC1 runs from this 5V supply. It has a rail-to-rail output at pin 3. That means the output will swing to a few millivolts off 5V when pin 3 is high and to a few millivolts shy of 0V when the output is low. The output drives resistances VR2 and the 220kΩ resistor in series to charge the 10nF capacitor connected to pins 2 and 6 when pin 3 is high and discharge when pin 3 is low.

When the pin 3 output is high, this capacitor charges to two thirds of the supply voltage, whereupon pin 6 detects this and sets the output low, discharging the capacitor. When the capacitor reaches one third of the supply voltage, pin 2 detects this and the pin 3 output goes high. The cycle continues, alternately charging and discharging the capacitor.

Since the capacitor is charged and discharged symmetrically between one and two thirds of the supply voltage via the same value resistance, the pin 3 output is a square wave with a 50% duty cycle.

The pin 3 output also drives emitter-follower buffer transistors Q2 and Q3 to drive the gate of MOSFET Q1 via a 10Ω resistor. When pin 3 is high, Q2 is switched on to charge Q1's gate, switching it on in turn. When pin 3 is low, Q3 switches on instead and the MOSFET's gate is discharged, turning it off.

The 5V supply rail and drain of the MOSFET are connected to the 150Ω resistor in the *Spark Energy Meter* via CON2 to provide the calibration signal. Note that the supply for the calibrator needs to be floating relative to that of the *Spark Energy Meter*. So long as the same 9V battery is not used to power both circuits, that will be the case. The two circuits should not be joined except via CON2.

Alternative circuit

The circuit diagram shows an alternative circuit that could be used after the *Spark Energy Meter* has been calibrated. You can then use this circuit as a pulse-width modulated power control for small DC motors or for lamps up to about 1A. The motor needs to be rated for 5V. For a higher voltage motor, you can connect between the minus terminal of CON2 and the plus terminal of CON1 to run at the input supply voltage (eg, 12V).

In this configuration, the 220kΩ resistor is replaced with a 1kΩ resistor and VR2 is replaced by a 250kΩ type. Diodes D3 and D4 are added so there will be a different charge and discharge path. When pin 3 is high, the 10nF capacitor is charged via D3 and the portion of VR2 to its wiper. During discharge, the capacitor is discharged via diode D4 and the opposite portion of VR2 to the wiper. So if VR2 is set to its mid point, the waveform should be close to a square wave as the resistance on either side of the trimpot wiper is the same.

The more VR2 is adjusted off centre the more the waveform becomes asymmetric. At the extremes of VR2, the output will be high for the ratio of 1/250 of each cycle when the wiper is wound anticlockwise and high for 249/250 when the wiper is fully clockwise. That way, the MOSFET can be switched to be on almost all the time or off most of the time or anywhere in between.

Next month

In the Part 2 article next month, we'll go through building the three PCBs, assembling the two main boards into the diecast case and the calibration and set-up procedure.

We'll also go over how to connect the spark energy meter to a working engine.

HAMMOND MANUFACTURING®

Enclosures for the hobbyist

- Raspberry Pi specific
- Arduino specific
- plastic
- die-cast aluminium
- many designs and sizes

+ 44 1256 812812 • sales@hammondmfg.eu • www.hammondmfg.com

Golden oldens

TechnoTalk

Mark Nelson

Or golden old 'uns, golden oldies or even good old faithfuls. Whatever you call them, there may be good reason for employing these old retainers. Mark Nelson, himself one of the old brigade, attempts to justify this assertion.

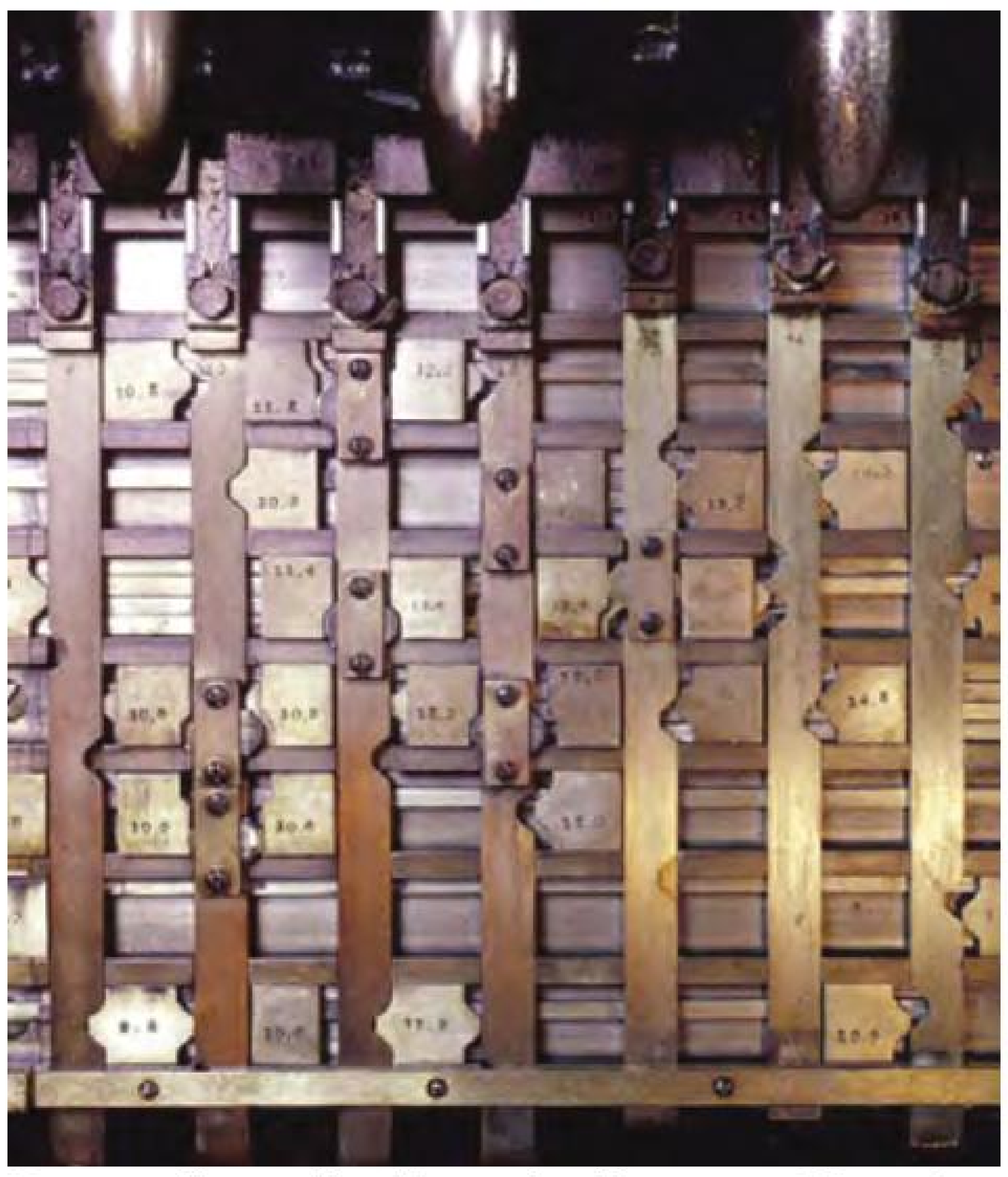
DID YOU SEE THAT NEWS STORY last year (November) about Orly Airport in Paris, where an elderly computer running the Windows 3.1 operating system had failed, causing the airport to close down for a while? Windows 3.1 dates from 1992 (almost prehistoric times) and the museum piece / collector's item was employed to communicate 'runway visual range' information to pilots, using custom software called DECOR. The failure left Orly unable to operate in fog. The Vice website quoted the secretary general of France's trade union for air traffic controllers as stating: 'The tools used by Aéroports de Paris controllers run on four different operating systems that are all between 10 and 20 years old. In Paris, we have only three specialists who can deal with DECOR-related issues. One of them is retiring next year, and we haven't found anyone to replace him.'

Maybe the airport should approach the hobby computer fraternity, where there is bound to be plenty of expertise among enthusiasts who would be pleased to exercise their skills for a meaningful purpose (and for some pocket money).

Does age matter?

The age of an operating system (and the software running on it) is not a factor if it still fulfills its required function, while old hardware can remain reliable for decades, so long as a supply of spare parts is maintained and a couple of standby machines are retained for 'hot standby' replacement. As this story has now gone cold, I imagine the problem was minor in nature (if not in its immediate consequences).

Criticism of the airport operators was fierce. Few commentators seemed to 'get it' that old tech can still be fit for purpose if certain common-sense rules are observed. After all, some of Britain's high-street banks still run veteran mainframe computers using COBOL, the common business-oriented language that dates from 1959. As Wikipedia states, COBOL is still widely used in legacy applications deployed on mainframe machines, such as large-scale batch and transaction processing jobs. Of course, owing to its declining popularity and the retirement of experienced COBOL programmers, programs are being migrated to new platforms, rewritten in modern languages or replaced with software packages.



Part of a 'locking bed' – a Victorian mechanical interlock system used to prevent railway signals and points from creating dangerous combinations.

Far older logic systems, some dating back to the nineteenth century, remain in use across Britain in railway signal cabins, using a complex arrangement of notched iron bars to prevent signals being set at 'all clear' unless the points have been set correctly and conflicting train movements are prevented (see photo). Most are on preserved railways, but a fair number are used on the main line system. And I could go on – but I won't; all I shall say is that if old technology still works (and is maintainable), why fuss? 'If it ain't broke, why fix it?' is a motto that still holds good in these financially straitened times.

The same applies in hobby electronics. Despite the plethora of fabulous new components on the market, plenty of new designs still use well-established op-amps, voltage regulators, timer chips and other parts that were new in the 1970s. We know and trust how they work and we probably still have little trays full of them. So it doesn't make you a bad person if you prefer to stick with them.

Hot stuff

Keeping faith with the old stuff was brought home to me this month, when I had a lot of soldering to do on tightly packed PCBs. I tend to use three separate soldering irons, each with different-sized bits to suit the task in hand. This time I needed the smallest size of bit, around 1mm, and I found that the iron with the 1mm bit was covered in flaky black scale. Attacking this scale with a wire brush and then a file didn't do much good. No matter, I decided to follow the advice that I give to everyone else, namely not to waste time with 1mm bits on conventional 25-watt soldering irons. The 1mm bits have a short and painful life, burning away, and common sense tells you to use a proper temperature-controlled iron that will not fry the bit to death.

We're talking about a man who never throws anything away, so I exhumed a faithful old temperature-controlled iron made by Oryx at least 30 years ago. It's the one with a fat red handle and a neon lamp to show that it's awake. I plugged it in – and bingo – it worked!

Brilliant – the only snag was that the bit measured 4mm across, far too big for soldering filigree work. OK, find the Oryx website and order up some smaller bits. Oops. No Oryx website to be found. Nor did Radiospares, Farnell or Rapid keep stocks. A firm in South Africa had loads of them, but the prices were elevated. Finally, good old Google pointed me towards the old-established business of S. R. Brewster (**www.soldering-shop.co.uk**), where joy of joys, they had an entire section devoted to bits for obsolete irons, at very modest prices too. I quickly bought two of each size and hope these will last me out. If you too are in need, I suggest you check this out soon, as stocks are strictly limited. 'Verb sap', as my Latin master said at school (he never explained what it meant, but I am sure Google knows).

End of an era

Here's another 'get it quick' alert. Cornfield Electronics (**http://cornfieldelectronics.com/tvbgone/tvbg.home.php**) has announced that it is ending production of the best electronic jape ever. The TV-B-Gone is a tiny TV remote control that has a single button, for OFF. Sequentially it sends out all the turn-off codes for scores of different brands of TV across a 20-to-50-foot range. If you have a grudge against large displays of TVs in big shops or just want to free up some personal space in a pub that has a noisy telly, this is the gadget for you!

Weardale Electronics
Custom leads, Components & Computing

Weardale Electronics

Suppliers of:
Electronic Components/Electrical Parts
Custom Designed Top Quality Instrument Leads
Computer Parts & Peripherals
Electronics Kits & Modules
Audio Leads & Adaptors
Website and Catalogue coming soon..

CONTACT INFO:
T: +44 (0) 1388 818502
E: stevewheatley52@gmail.com
10 Mount Pleasant Close
Spennymoor
DL16 6EU
Callers Strictly by
Appointment only.
UK VAT Registered
All prices include VAT @ 20%

BARGAIN COMPONENT PACKS
78LO5 PACK OF 10 £1
IN4007 PACK OF 30 £1
GL5516 LDR PACK OF 5 £1
NE555P+SKTS PACK OF 5 £1
5mm UB WHITE LED PACK OF 50 £1
ASS TRIMPOTS PACK OF 10 £2
4017BE + SKTS PACK OF 3 £1.50
BTA12-600TW PACK OF 4 £3.00
CD4013BE PACK OF 5 £1.50
2N2222A PACK OF 15 £1
10cm x 16cm STRIPBOARD £3.50
PP3 BATT CLIP HQ PK OF 3 £1
10A10 DIODES PACK OF 5 £1
PCB RELAY 12VDC COIL PACK/4 £2
7 SEG LED DISPLAY RED PACK/5 £1
GL5549 PHOTO RESISTOR PACK/4 £1
THERMISTOR 10K0 PACK OF 4 £1
IN4148 DIODE PACK OF 50 £1
LM324N QUAD OP AMP PACK/5 £1
LM317T V/REG PACK OF 3 £1

EMAIL OR SEND YOUR ORDER
Payment - Paypal, Cheque or Postal Order.
P+P £3.50 (max) per order RM 1st Class.
All components are branded or Top Quality.
"LIKE" on Facebook for s/h bargains/offers.
https://www.facebook.com/weardaleelectronics

CUSTOM DESIGNED GUITAR & INSTRUMENT LEADS MADE TO YOUR OWN SPECIFICATIONS
Guitar Leads
Microphone leads
Patch leads
Speaker leads
Audio interconnects
Adaptors etc etc

TOP QUALITY CABLE & PARTS
Van Damme Cable
Sommer Spirit Cable
Klotz cable
Neutrik Connectors
Amphenol Connectors
ALL LEADS GUARANTEED
Email me for details and free quotations.

VISIT THE EBAY WEARDALE ELECTRONICS SHOP FOR LATEST ITEMS.
LEAVE A PAYPAL NOTE WITH YOUR PAYMENT STATING "EPEMAGAD1"
AND GET 10% OFF YOUR TOTAL ORDER VALUE.
http://stores.ebay.co.uk/weardaleelectronics

Secure Payments By PayPal
NO PAYPAL ACCOUNT NEEDED!

Visit our ebay store

Hobbyists: Vero supports you!

Prototyping boards, terminal pins, test points and enclosures
All UK manufactured: see our complete range at verotl.com

Veroboard – the original, and still the best
- Stripboard, square pad board and many other designs
- Many different sizes
- www.verotl.com/en/category/veroboard

Test points and terminal pins
- PTH and SMT test points
- Many different terminal pin designs
- www.verotl.com/en/category/test-points

Plastic enclosures
- Small, hand-held and desktop designs
- IP rated water and dust protection
- Solid and translucent colours
- www.verotl.com/en/category/plastic-enclosures

Call 01489 776933 or mail sales@verotech.co.uk to discuss your project.
Order standard products ex stock online at verotl.com.
Pay by credit card or PayPal

vero TECHNOLOGIES

6-Digit Retro Nixie Clock

. . . with optional GPS time

Revel in the retro glow of this cool Nixie Clock. But while it looks like something out of the 1960s, this is a modern design utilising a 32-bit microprocessor and (optionally) a GPS receiver module to always give you accurate time and date, automatically determined by your location. We've also added a date display function, a 7-day alarm and other nice features.

Part 1: By Nicholas Vinen

Features and specifications

- 6-digit Nixie clock with date display, 7-day alarm and snooze functions
- Blue LEDs to provide effect lighting; can be switched on or off
- Locked to GPS time to within a fraction of a second (if GPS module is fitted)
- Automatically determines time zone and daylight saving zone in UK, Australia, New Zealand, USA, Canada and Western Europe
- Time zone override for other locations or daylight saving rules change
- Without GPS, timekeeping crystal can be trimmed to keep accurate time within less than one second per month
- Auto-dimming of Nixie tubes and blue LEDs
- Proximity sensor for easy date display
- Keeps time for several hours during mains power failure
- Easy to set time and date via two-button interface
- 12/24-hour time and leading-zero blanking options
- All through-hole components to simplify construction
- Complete kit available, including clear acrylic case.

This photo doesn't really do the clock justice. The glowing colours from the Nixie displays and the blue LEDs are actually quite a lot brighter and more dynamic than this photograph shows.

WE'VE HAD SO many people ask us about Nixie Clocks that we decided it was time for a super project.

Essentially, a Nixie tube is a neon-filled tube with 10 differently-shaped cathodes. A high voltage is applied between the anode and one of the cathodes, causing the gas around that cathode to become excited and glow. Nixies were used heavily before vacuum fluorescent displays, LED 7-segment displays and LCDs replaced them.

The biggest drawback of Nixie tubes, apart from the high voltage required to drive them (150V+), is their complex construction and thus cost. This type of Nixie tube is no longer manufactured and what stock is left will only get more expensive over time – so, if you want to build one of these clocks, now is the time!

What will it do, besides display the current time (hours, minutes and seconds) on the six Nixie tubes which protrude from the top of the clear acrylic case? Well, it also keeps track of the date and will display it if you wave your hand in front of the unit. It also has a 7-day alarm with a piezo buzzer and options for 12/24-hour time display and leading zero blanking.

In addition, it can be GPS-locked, so that you never have to set or adjust it. It even automatically adjusts for daylight saving time. It has blue LEDs under the Nixie tubes that can be switched on and off to add extra visual appeal.

Circuit description

Fig.1 shows the control portion of the circuit, which is built onto the lower PCB. The Nixie tubes and LEDs are on the upper PCB and this part of the circuit is shown in Fig.2.

PIC micro

At the heart of the control circuit in Fig.1 is microcontroller IC1, a PIC32MX170F256B. This is a 32-bit, 40MHz chip with 64KB RAM and 256KB Flash memory in a 28-pin DIP package. Such is the march of progress that this powerful microcontroller costs less than an 8-bit chip (with just a measly few kilobytes of Flash and RAM) just a few years ago.

This large amount of Flash memory allows us to do some fancy things regarding time zones, which we'll get to later. For now, let's just look at how it keeps time, drives the Nixie tubes and communicates with the GPS module, if it's fitted.

IC1 runs from a 3.3V supply and has a 32.768kHz watch crystal connected between pins 11 and 12 (SOSCI/SOSCO) with 22pF load capacitors on each pin. An internal low-power amplifier drives this crystal to form the 'secondary oscillator' and this is connected internally to a Real Time Clock and Calendar module (RTCC), which keeps time even when the micro is in sleep mode.

An internal clock trim register adds or subtracts a configurable number of pulses every 10 seconds to allow for inaccuracies in the crystal frequency to be adjusted out.

Nixie segments

There are a total of 46 Nixie segments that we need to drive for the time or date display. For ND2, ND4 and ND6 (Fig.2) we drive all 10, as these are the units digits for hours, minutes and seconds. When displaying the date, these are used instead to show the day, month and year respectively.

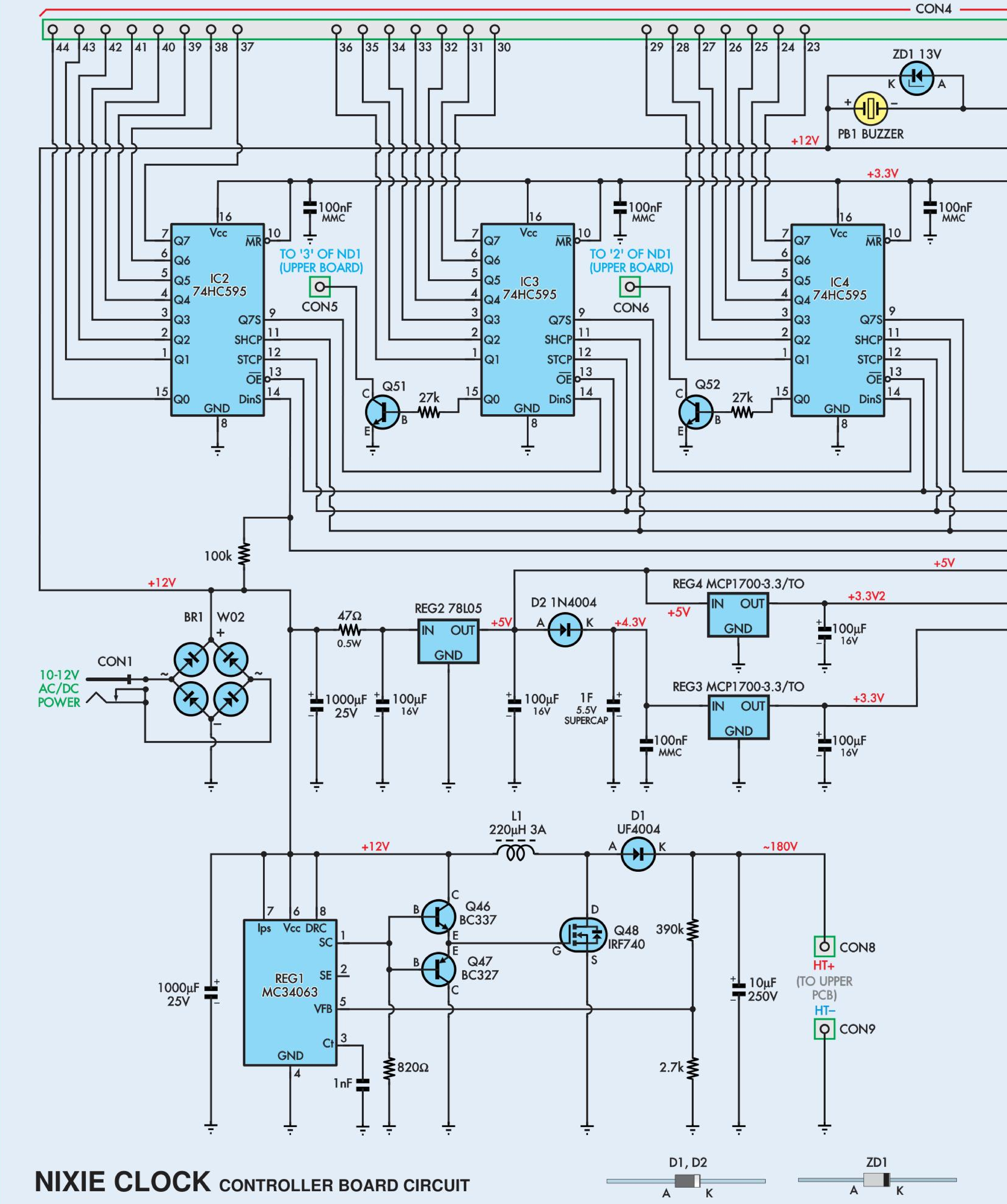
For ND3 and ND5, the 10s digits for minutes and seconds (or month and year when displaying date), we only drive segments 0-5. Similarly, with ND1, we only drive segments 0-2 for the hours (time display) 10s digit or 0-3 for the day (date display) 10s digit.

44 of the 46 Nixie segment connections are made via CON4/CON10, which are rows of pads along the front edge of the two PCBs that are connected via 27kΩ resistors soldered between the boards. The other two connections are made using wires connected to PCB pins CON5 and CON6.

Returning to Fig.1, nine of these 46 lines are driven directly from IC1's outputs RB1-RB3 (pins 5-7) and RB7-RB12 (pins 16-18 and pins 21-23). Since we don't have enough pins on the micro to drive all 46 segments, the other 37 are driven instead by the outputs of five 74HC595 serial-to-parallel shift registers, IC2-IC6.

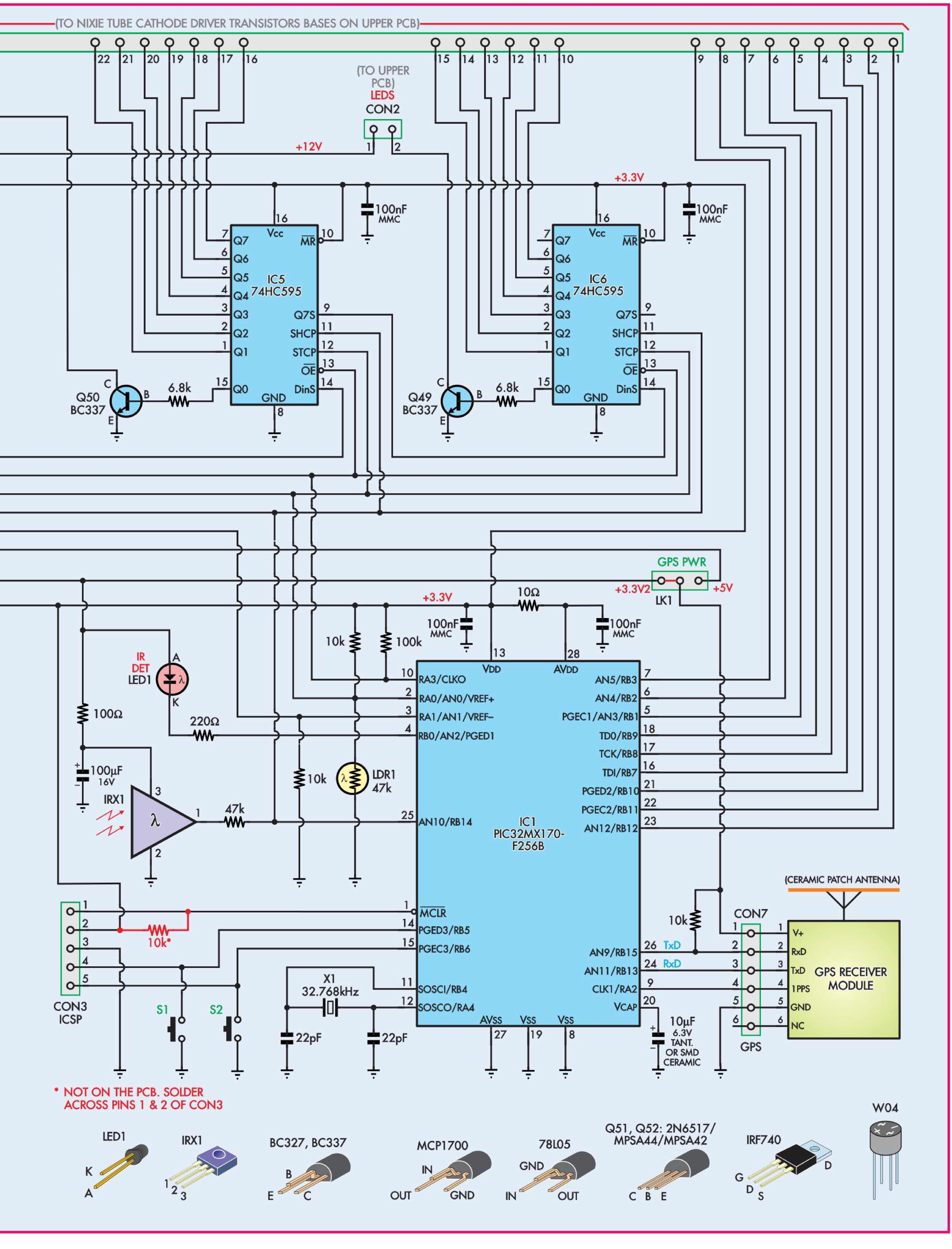
These ICs are controlled by the micro using outputs RA1 (serial data output, pin 3), RB14 (serial clock, pin 25), RA0 (register latch, pin 2) and RA3 (output enable, pin 10). To change which Nixie digits are lit, IC1 delivers 5 × 8 = 40 bits of data on RA1, clocked using RB14, then brings RA0 high to update the outputs of IC2-IC6 simultaneously. It then immediately updates the output stage of the other nine control lines.

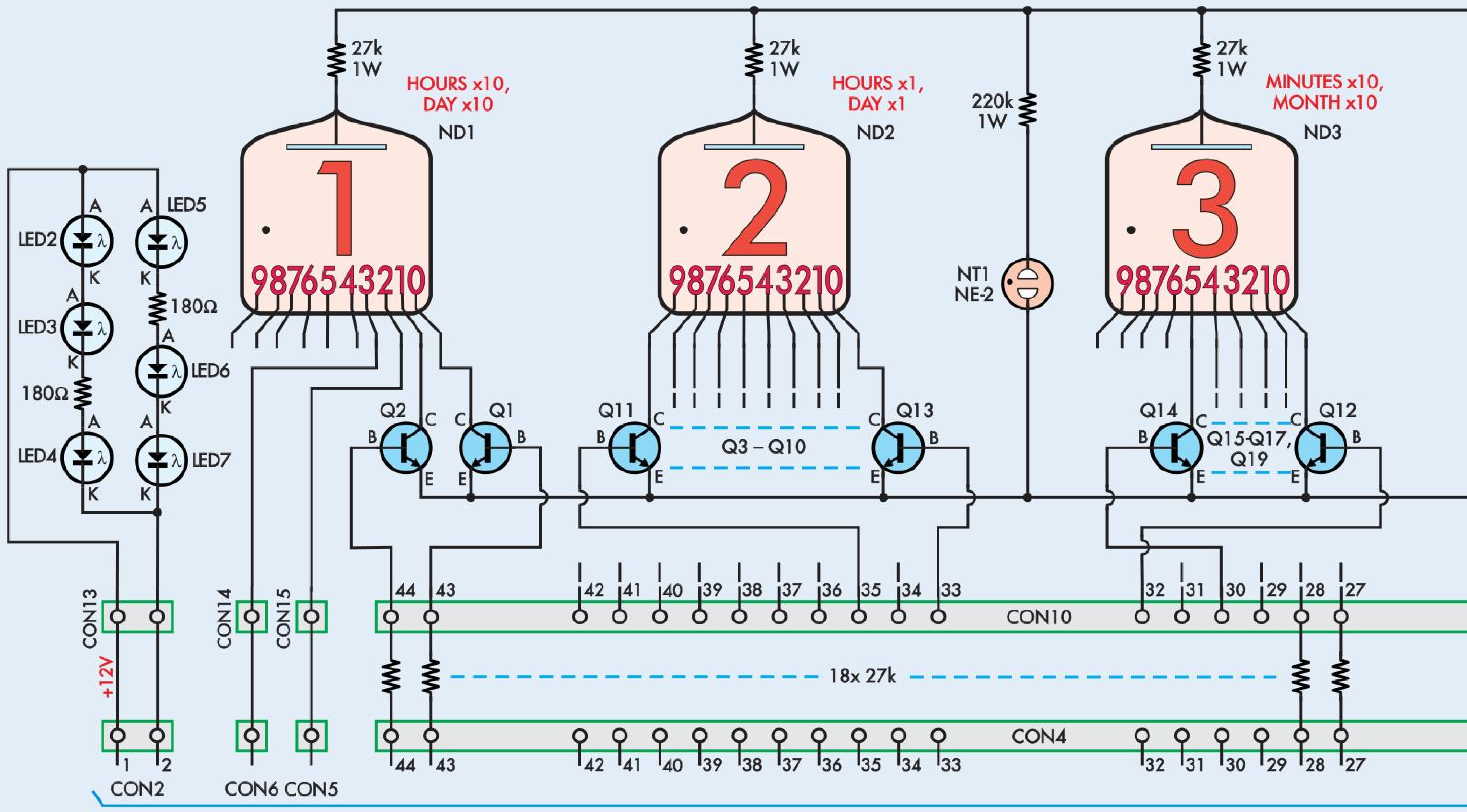
Each of these 46 lines drives the base of a high-voltage NPN transistor, Q1-Q46, via 27kΩ current-limiting resistors. Thus, with an output high at 3.3V, the base current is (3.3V-0.6V) ÷ 27kΩ = 0.1mA. The Nixie tubes draw about 1-2mA and the transistors typically have an h_{FE} of around 40, so Q1-Q46 will be driven into saturation.


CON4
44 43 42 41 40 39 38 37
36 35 34 33 32 31 30
29 28 27 26 25 24 23
ZD1 13V
K A
+ −
PB1 BUZZER
+12V
+3.3V
100nF MMC
IC2 74HC595
IC3 74HC595
IC4 74HC595
16 Vcc
MR 10
Q7 Q6 Q5 Q4 Q3 Q2 Q1 Q0
Q7S SHCP STCP OE DinS
GND 8
TO '3' OF ND1 (UPPER BOARD)
CON5
TO '2' OF ND1 (UPPER BOARD)
CON6
Q51
Q52
C B E
27k
100k
+12V
BR1 W02
CON1
10-12V AC/DC POWER
47Ω 0.5W
1000µF 25V
100µF 16V
REG2 78L05
IN OUT GND
+5V
D2 1N4004
A K
+4.3V
1F 5.5V SUPERCAP
100nF MMC
REG4 MCP1700-3.3/TO
+3.3V2
REG3 MCP1700-3.3/TO
+3.3V
+5V
L1 220µH 3A
D1 UF4004
~180V
+12V
Ips Vcc DRC
SC SE VFB Ct
REG1 MC34063
GND
7 6 8 1 2 5 3 4
Q46 BC337
Q47 BC327
Q48 IRF740
D G S
390k
2.7k
820Ω
1nF
1000µF 25V
10µF 250V
CON8
HT+
(TO UPPER PCB)
HT−
CON9
D1, D2
ZD1
A K

NIXIE CLOCK CONTROLLER BOARD CIRCUIT

Fig.1: the circuit for the lower (control) board of the *Nixie Clock*. Microcontroller IC1 keeps time using crystal X1 and, if fitted, the GPS receiver via CON7. This micro drives the Nixie tubes via CON4 using nine of its own output pins plus 37 from serial-to-parallel latches IC2-IC6. REG1 generates the 180V HT rail for the Nixies, while REG2-REG4 supply power to the micro and associated circuitry. LED1 and IRX1 are used as a proximity sensor to trigger date display.


(TO NIXIE TUBE CATHODE DRIVER TRANSISTORS BASES ON UPPER PCB)
22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
(TO UPPER PCB) LEDS
CON2
+12V
+3.3V
100nF MMC
IC5 74HC595
IC6 74HC595
Vcc
MR
Q7 Q6 Q5 Q4 Q3 Q2 Q1 Q0
Q7S SHCP STCP OE DinS
GND
Q50 BC337
Q49 BC337
C B E
6.8k
GPS PWR
+3.3V2
+5V
LK1
10Ω
100nF MMC
10k
100k
IR DET LED1
A K
100Ω
220Ω
100µF 16V
IRX1
47k
10k
LDR1 47k
IC1 PIC32MX170-F256B
VDD AVDD
RA3/CLKO
RA0/AN0/VREF+
RA1/AN1/VREF–
RB0/AN2/PGED1
AN10/RB14
MCLR
PGED3/RB5
PGEC3/RB6
SOSCI/RB4
SOSCO/RA4
AVSS VSS VSS
AN5/RB3
AN4/RB2
PGEC1/AN3/RB1
TD0/RB9
TCK/RB8
TDI/RB7
PGED2/RB10
PGEC2/RB11
AN12/RB12
AN9/RB15
AN11/RB13
CLK1/RA2
VCAP
TxD
RxD
10k
10µF 6.3V TANT. OR SMD CERAMIC
X1 32.768kHz
22pF
22pF
CON3 ICSP
10k*
S1
S2
CON7
GPS
(CERAMIC PATCH ANTENNA)
GPS RECEIVER MODULE
V+ RxD TxD 1PPS GND NC
* NOT ON THE PCB. SOLDER ACROSS PINS 1 & 2 OF CON3
LED1
IRX1
BC327, BC337
MCP1700
78L05
Q51, Q52: 2N6517/ MPSA44/MPSA42
IRF740
W04
IN OUT GND
G D S



NIXIE CLOCK DISPLAY BOARD CIRCUIT

Fig.2: the upper board circuit has the six Nixie tubes, 44 of the 46 driver transistors plus the neons that separate hours/ minutes/seconds and six blue LEDs to illuminate the Nixie tubes. The 27kΩ base resistors for the 44 driver transistors are strung between the two boards, ie, between CON4 and CON10, which are slotted edge connectors.

We're only using 37 of the 40 total output pins for ICs2-6 to drive Nixie segments. One of the remaining outputs (pin 7 of IC6) is unused, while the other two drive the piezo buzzer (for the alarm function) and the blue LEDs mounted under the Nixie tubes. Thus, the LEDs are under software control and can be easily dimmed or switched off if required.

Power supply

The clock is powered from a 10-12V AC or DC supply, plugged into DC socket CON1. The ~180V DC used to drive the Nixie tubes is derived from this via a boost converter.

Bridge rectifier BR1 rectifies the AC or if a DC supply is used, provides reverse polarity protection. The resulting DC is smoothed with a 1000µF capacitor. This then feeds REG2, a 78L05 5V regulator, via a 47Ω/100µF RC filter.

The main purpose of the 47Ω resistor is to reduce the dissipation in REG2 when the filtered DC voltage is on the high side. It will dissipate up to 500mW with a 15V DC supply (eg, 12V AC rectified) and a 100mA draw on the 5V line. Under these conditions, REG2 will also dissipate 500mW, just under its 625mW maximum rating.

The output of REG2 is used to power a 5V GPS module, if fitted. It also charges a 1F super capacitor via diode D2, resulting in around 4.3V. Low-dropout (LDO) regulator REG3 derives the 3.3V for IC1 from this 4.3V input.

Thus, if there is a mains power failure, IC1 will continue to run off the charge in the super capacitor. By disabling all its outputs and dropping into a sleep mode, it can continue to keep time for many hours until the mains power comes back.

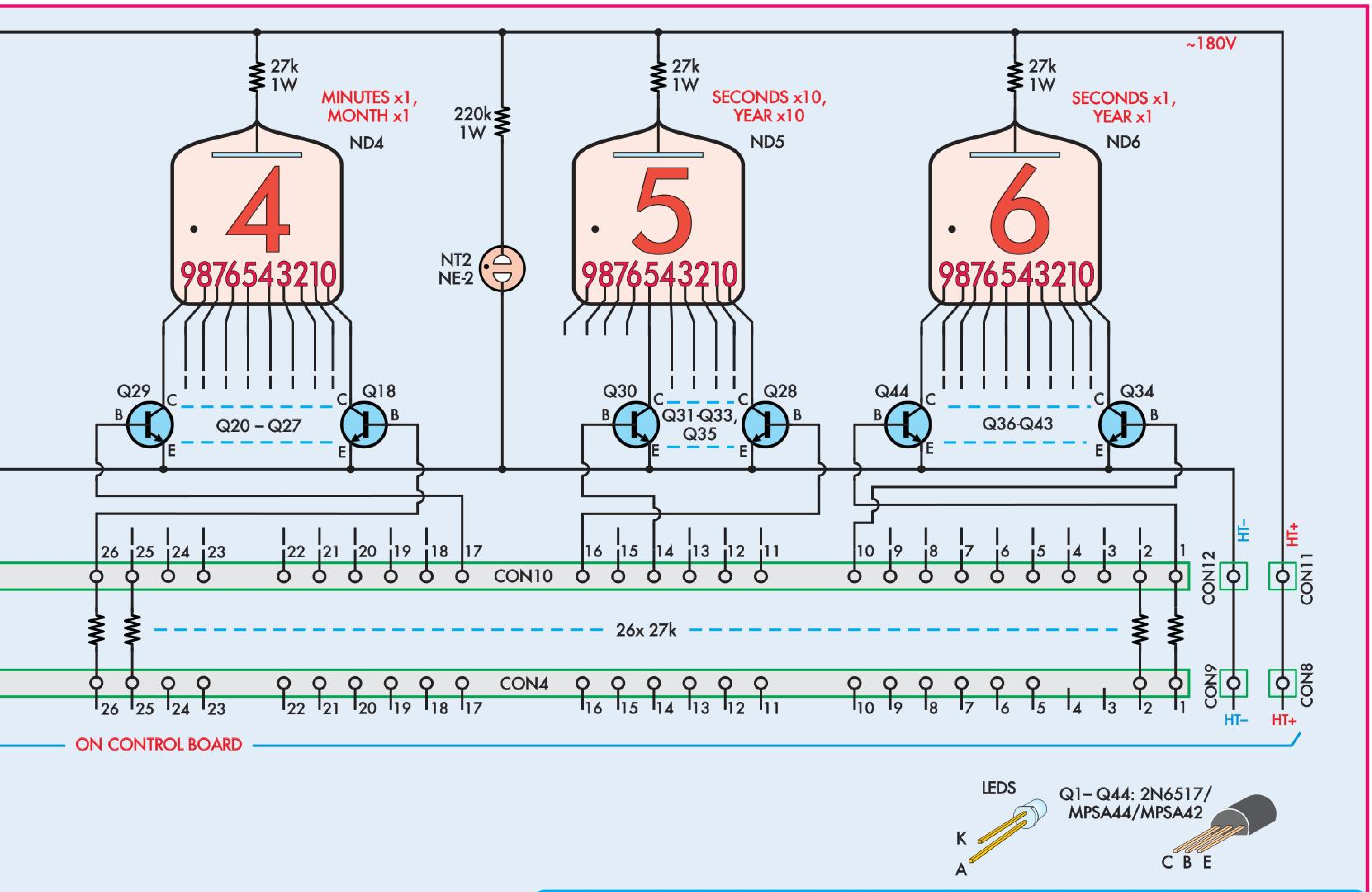
A second identical 3.3V LDO, REG4, is used to supply power for a 3.3V GPS module (if fitted) and also powers some of the ancillary circuitry such as the infrared proximity detector. This regulator is fed directly from the 5V output of REG2 – so if mains power fails, the GPS and proximity detector will power down immediately. LK1 selects whether the GPS module runs from the 3.3V or 5V supply.

HT supply

REG1 forms the boost converter and this runs directly off the rectified and filtered supply of around 12-15V DC. The 1nF capacitor between pins 3 and 4 (C_T and GND) sets its oscillation frequency to around 33kHz.

When its switch output at pin 1 goes high, the gate of MOSFET Q48 is driven high via an emitter-follower buffer comprising NPN transistor Q46 and PNP transistor Q47. This buffer is required because pin 1 is an open-collector output, and while it has good pull-up strength, a very low value resistor would be required to discharge the gate of Q48 quickly at switch-off. The buffer allows a higher value pull-down resistor (820Ω) to be used while keeping switching time fast.

When Q48's gate is driven high and it turns on, current flows from the ~12V DC supply, through inductor L1, through Q48 and to ground. This is effectively a short circuit across L1 and causes its magnetic field to rapidly charge. Its inductance, combined with IC1's limit on the on-time,



prevents this current flow from becoming excessive.

When Q48 is switched off, this magnetic field causes current to continue to flow in the same direction through L1 but the only path is then from ground, through ultrafast diode D1 and into the 10µF 250V capacitor. As a result, the voltage at this end of the inductor shoots up well above the 12V input. Current flow drops off as L1's magnetic field collapses, until Q1 switches on again and the process repeats.

IC1 monitors the voltage across the 10µF capacitor using a 390kΩ/2.7kΩ resistive divider and adjusts the duty cycle with which Q48 is driven to maintain 1.25V at its feedback pin (pin 5). This regulates the voltage across the 10µF capacitor to 1.25V x (390kΩ ÷ 2.7kΩ + 1) = 182V. This then supplies the Nixie tube and neon lamp anodes.

GPS interface

CON7 provides the connections for a GPS module. There are two power supply pins – 3.3V/5V (depending on the module used) and 0V (GND). There are two serial pins, for transmit and receive, although the receive pin is not terribly important as most modules will send the required data without prompting. It's there for completeness.

Note that we're assuming that if a 5V GPS module is used, it has a 3.3V serial interface. That is typically the case – eg, the GlobalSat EM-406A requires a 5V supply and uses a serial signalling level of around 2.85V, while the VK16E can run off either 3.3V or 5V (or anything in between) and its TxD pin will produce a maximum voltage of 3.6V. Hence, we have no over-voltage protection for IC1's RxD input beyond the normal internal clamp diode. Refer to the panel on suitable GPS modules for more information.

The remaining GPS pin is for a 1pps (one pulse per second) signal from the GPS module to the micro. This is used so that the seconds 'tick' is accurately synchronised. However, should you use a module without a 1pps output, the clock will still be synchronised to GPS time. It's just that it could be off by half a second or so. Most people will not care about this.

Suitable GPS modules

The following GPS modules should be suitable for use in this project: GlobalSat EM-406A, Fastrax UP501 and VK16E. The Digilent PmodGPS and RF Solutions GPS-622R should also work but will not fit on the board unless mounted on top of a non-conductive spacer (which we recommend, anyway). Most other modules that will fit on the board should also be suitable, but if they run off 5V you will need to check that the serial output voltage does not exceed 3.6V.

Note that a few GPS modules are available with onboard RS-232 level converters and so deliver ±12V or similar on the TxD line. These can also be used in the Nixie Clock Mk2 but you must connect a 4-7kΩ–10kΩ resistor in series between the module and pin 3 of CON7 to avoid damaging microcontroller IC1.

Note also that the GPS module isn't normally included with the kit, but will be offered as an optional extra (or you can supply your own).

Nixie Clock Kit Parts List

1 control (lower) PCB, code 19102151/NX15L, 144 × 64mm
1 display (upper) PCB, code 19102152/NX14U, 144 × 64mm
1 9-12V 250mA AC or DC plugpack
1 PCB-mount DC socket
1 perspex case
6 1N14 Nixie tubes, 14-pin bases (ND1-ND6)
2 NE-2 neon lamps (NT1,NT2)
1 220µF 3A toroidal inductor (L1)
1 32.768kHz watch crystal, 10pF load capacitance (X1)
1 3-pin header with shorting block (LK1)
1 2-pin header, 2.54mm pitch (CON2)
1 5-pin header, 2.54mm pitch (CON3) (ICSP, optional)
4 1mm PCB pins (CON5,CON6, CON8,CON9)
1 6-pin header for GPS, 2.54mm pitch (CON7)
2 40-pin snappable machined socket strips (to make Nixie sockets)
1 mini 9-14V piezo buzzer, 7.62mm pin spacing (PB1)
1 47-100kΩ LDR (LDR1)
2 PCB-mount horizontal momentary pushbuttons (S1,S2)
1 GPS module with suitable connection cable (optional)
1 length double-sided tape (to affix GPS module)
1 plastic block, ~20 × 20 × 8mm (to affix GPS module)
1 250mm-length 1.5mm heatshrink tubing
4 25mm tapped metal spacers
4 12mm tapped male/female metal spacers
8 M3 × 8mm pan-head machine screws
12 4G × 12mm self-tapping screws (supplied with perspex case)
Assorted lengths of medium-duty hook-up wire
1 black card, 24 × 12mm

Semiconductors
1 PIC32MX170F256B-I/SP 32-bit microcontroller programmed with 1910215A.hex
5 74HC595 serial to parallel latch ICs (IC2-IC6)
1 infrared receiver (IRX1)
1 MC34063 switch-mode regulator (REG1)
1 78L05 5V 100mA regulator (REG2)
2 MCP1700-3.3/TO 3.3V micropower low-dropout regulators (REG3,REG4)
46 2N6517, MPSA42 or MPSA44 high-voltage transistors (Q1-Q44, Q51-Q52)
3 BC337 NPN transistors (Q46, Q49,Q50)
1 BC327 PNP transistor (Q47)
1 IRF740 400V 10A MOSFET (Q48)
1 13V 1W Zener diode (ZD1)
1 infrared LED (LED1)
6 blue 3mm LEDs, clear lenses (LED2-LED7)
1 W02/W04 1.5A bridge rectifier (BR1)
1 UF4004 ultrafast 400V diode (D1)
1 1N4007 1A 1000V diode (D2)

Capacitors
1 1F 5.5V super capacitor
1 1000µF 25V electrolytic
5 100µF 16V electrolytic
1 10-100µF 6.3V tantalum or 10µF SMD ceramic
1 10µF 250V electrolytic
8 100nF multi-layer ceramic
1 1nF MKT, ceramic or polyester
2 22pF ceramic

Resistors (0.25W, 1%)
1 390kΩ
2 220kΩ 1W 5%
2 100kΩ
1 47kΩ
6 27kΩ 1W 5%
46 27kΩ
3 10kΩ
2 6.8kΩ
1 2.7kΩ
1 820Ω
1 220Ω
2 180Ω
1 100Ω
1 47Ω
1 10Ω

Where To Buy A Kit

The Nixie Clock is available exclusively as a complete kit from Gless Audio. This includes the PCBs, all components, a programmed microcontroller, Nixie tubes and the case hardware.

Contact Gless Audio on +61 (0)403 055 374/+61 (0)39 442 3991 or email: **glesstron@msn.com**

Just wave for the date

Because it's inconvenient having to reach around the back of the unit to press a button when you want to see the date, we've fitted a simple proximity sensor. All you have to do is wave your hand in front of the unit and it will show the date for 10 seconds, then switch back to showing the time.

This is implemented using an infrared LED (LED1) and infrared receiver IRX1. LED1 has a series 220Ω current-limiting resistor and is driven directly from microcontroller output RB0 (pin 4). This is configured as a PWM output via the internal Peripheral Pin Select crossbar.

Periodically, based on a timer interrupt, this PWM output is enabled and driven at 38kHz with a low duty cycle. Some of the emitted infrared light pulses reflect back to IRD1 which detects this signal and its output goes low.

Depending on the proximity of objects to LED1 and IRX1, some of this light is reflected, resulting in a variable length output pulse. IC1 detects changes in the length of this pulse as indicating movement of nearby objects and responds by showing the date.

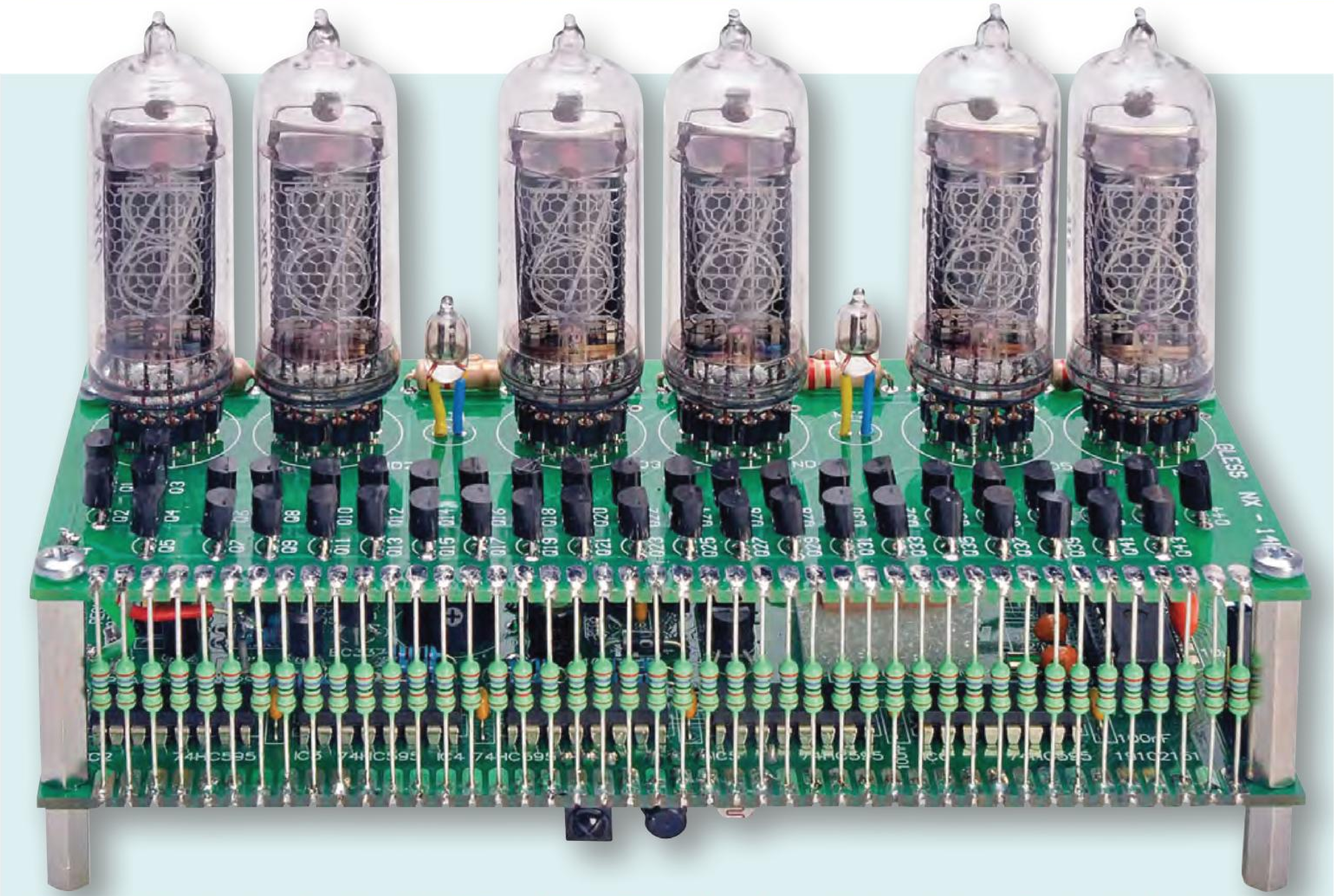
Because there are no spare pins on IC1, the infrared receiver signal is connected to pin 25 via a 47kΩ resistor. This pin is also used to drive the SCK (serial clock) lines of serial latches IC2-IC6 – however, it's only driven when there is serial data to send. The 47kΩ resistor isolates the infrared receiver output during this time. The rest of the time, IC1 can sense the output level from IRD1.

Pins 2 and 3 of IC1 are similarly used for dual purposes. Both have resistive voltage dividers connected which are 'overridden' when those pins are being used as outputs, to drive the latch clock lines of IC2-IC5 and the serial data lines respectively.

Pin 2 is used to monitor ambient light levels using LDR1, while pin 3 is used to (indirectly) monitor the mains supply voltage. Both are 'read' by IC1 using its internal analogue-to-digital converter (ADC).

For pin 2, as the light level drops, LDR1's resistance increases and so the voltage at this pin approaches the positive rail. This allows the unit to adjust the Nixie tube and LED brightness so it isn't overpowering in a dark room.

Pin 3 is connected to the filtered DC supply via an 11:1 voltage divider (ie, 100kΩ ÷ 10kΩ + 1). The voltage on this pin is periodically checked and if it drops below 0.64V, indicating less



The unit is built on two double-sided PCBs, with the Nixie tubes plugged into sockets on the top display board. The GPS module, microcontroller and time-keeping circuitry are on the lower control PCB. Part 2 next month has the full constructional details.

than 7V on the main filter capacitor, it is assumed that the mains power has failed (or been unplugged). In this case, IC1 turns off all its outputs and goes into sleep mode, to minimise the discharge rate of the 1F supercap.

The current drain in this mode is around 40µA and the real-time clock continues to run. At this rate, the clock should be able to keep time for a week or more until power is restored. IC1 'wakes up' every few seconds and checks the voltage on this pin again. Once it rises above 0.73V, mains power has resumed and so the chip switches back to normal operation.

Note that the LDR voltage is being read immediately after updating the data in latches IC2-IC5 so that, should the resulting voltage be low enough to effectively toggle the register latch inputs of these ICs, it will not change the state of the 40 output pins; they will merely re-latch the same data just sent.

User interface

Besides the proximity sensor, which is used to display the date and snooze the alarm, there are only two pushbuttons to control the clock, labelled S1 and S2. These are connected to pins 14 and 15 of IC1 which are set up as inputs PB5 and PB6 with internal pull-up resistors enabled. The chip's Change Notification Interrupt feature is used to detect when a button is pressed, pulling one of these lines low.

These lines are also the programming interface (PGED and PGEC) and are connected to in-circuit serial programming header CON3. However, those functions are only operational when the unit is in programming mode, initiated by pulling pin 1 (MCLR) to a high programming voltage, so they don't interfere with button sensing.

There are a large number of functions available using these two buttons, including: setting the time and date (when a GPS module is not fitted), manually setting the time zone (with GPS fitted), trimming the crystal frequency, setting and viewing the alarm, turning the alarm on and off and changing various options such as 12/24-hour time and leading zero blanking.

To handle all these different cases, the unit detects long and short presses of the two buttons and also combination presses: both buttons pressed simultaneously, both buttons held down or one button held down and the other pressed. These various combinations allow the user to get into the different modes necessary to access the above functions.

Piezo buzzer

Piezo buzzer PB1 is used to sound the alarm and is driven by NPN transistor Q50 from output Q0 of serial latch IC5. This buzzer can run off 9-14V. Since it's possible for the unfiltered DC supply to be slightly higher than this (depending on the plugpack used), 13V zener diode ZD1 is connected across the buzzer to limit the maximum voltage applied.

The current through this zener is limited by the drive capabilities of Q50. Its base current is around 0.4mA and with a typical h_{FE} of 150 it will therefore sink about 60mA if ZD1 conducts – about 30mA through PB1 and 30mA through ZD1.

The blue LEDs are powered via NPN transistor Q49, which is driven from the Q0 output of serial latch IC6.

Determining local time using GPS

If a GPS module is fitted to this unit, once it has acquired enough satellites, it automatically broadcasts the current time and date at its serial output pin. However, this time and date are in Universal Co-ordinated Time (UTC) which is almost identical to Greenwich Mean Time (GMT).

To figure out your local date and time, we need to know which time zone you are in and what your daylight saving rules are. Based on this information, we can then compute the local time. Once we know the time zone, this just involves adding the local time zone offset to the UTC time and date, then checking the local daylight savings rules and if applicable, adding the DST offset.

The tricky part is figuring out the current time zone. Once it has a fix, the GPS module provides its location as a latitude, longitude and altitude. To figure out what time zone you are in from this information, we need a map which defines all time zone boundaries and rules.

We initially considered using a free database called tz_world. This contains thousands of regions, defined by strings of lat/long pairs which make up their boundaries (as closed polygons) and each region is then associated with a time zone by name.

Unfortunately, tz_world is many megabytes. It could be loaded onto something like a Raspberry Pi or Beaglebone Black, but even then, the calculations to go through those thousands of polygons (many of which are bounded by thousands of points) would take some time, even with a fast processor.

After some effort, we managed to extract enough information from this database to be useful and compress it into a much smaller size. The end result is a little under 100KB of data which contains enough information to determine whether a given lat/long is within any time zone for Australia, New Zealand, the UK, the USA, Canada or Western Europe.

After extracting this information, we simplified it as much as possible without compromising the accuracy. For example, we merged the zones for New South Wales, Victoria and Tasmania since they operate under the same rules and this eliminates the need to store the detail of the NSW/Victoria border. We also removed most of the coastal detail as it really isn't necessary. If you are using the Nixie Clock at sea, it will simply show time in the time zone for the nearest land mass.

We also found that tz_world defined straight lines or nearly straight lines (eg, most of the borders between Australian states) as a number of points in the polygon when we only really need to store the two end points. Removing the unnecessary intermediate points allowed further reductions in size.

Delta compression

Finally, we applied a variable bit length delta compression to the data. Essentially, when a region is defined as 'n' lat/long pairs, we don't need to store each pair separately. Rather, we can store the first pair, then the two-coordinate distance vector between subsequent pairs. Because each point bounding a region is usually quite close to the last, these 'delta' values tend to be much smaller than the original lat/long values.

We store the values in thousandths of a degree. For example, Sydney is at 33.86°S, 151.2094°E (approximately). We store this as integers -338600,1512094 which takes approximately 48 bits of data space, ie, 6 bytes.

Say that is the first point in a region and the second is 33.85°S, 151.28°E. Rather than storing this second pair and using up another 6 bytes, we can store a delta of +0.01°,-0.0706° instead. Converting this to our integral format yields values of +10,-71. We can store delta pairs of up to ±0.1° in 16 bits, so this delta takes up 1/3 the number of bytes compared to the absolute location.

Similarly, deltas of up to ±0.0723° in lat/long can be stored in 24 bits (3 bytes, 1/2 the space) and up to ±1° in 32 bits (4 bytes, 2/3 the space). Very few co-ordinate pairs are further than 1° apart and on average, our scheme uses less than half the space required to just store the lat/long pairs.

Decompressing the data is simple and quick; the size of the next delta is stored in the first few bits of data, with the deltas themselves following. We then read these values and simply add them to the last decoded co-ordinate to get the next one.

Time zone search

Once we had created the database of time zone boundaries, we needed a way to figure out if the current lat/long is within each region. That's not as simple as you might think given the complexity of some of these shapes. We need a way to determine whether a point is within a polygon by examining the points which define its vertices.

Before doing this though, we look at the lowest and highest lat/long values in the set of vertices and compare these to the current lat/long. If it's outside that bounding box, it can't possibly be within the time zone polygon and so we can skip that zone entirely.

Assuming that our lat/long is within the bounding box, we must then do the full polygon check. First we pick a random co-ordinate (lat/long) that's definitely outside the time zone boundary, using the bounding box as a guide. We then draw an imaginary line from our present position to that random position which we know is outside the time zone being considered.

If the current lat/long is within the polygon, that imaginary line will intersect the bounding line segments an odd number of times – most likely once, but possibly three or five times say. If we are outside it, the imaginary line will intersect the boundary lines an even number of times – probably zero, but possibly two (if our position and the random position

Software

The software for this unit, while fairly complex (to handle all the various modes), is straightforward. Its main job is to set up the real-time clock, wait for a second to pass, then drive the appropriate Nixie segments to display the correct time. Simultaneously, it monitors the GPS serial and 1pps signals for time/date updates and also monitors the pushbuttons, LDR, infrared receiver and supply voltage.

The most complex part of the software involves handling time zones correctly. Simply getting the time from a GPS receiver is quite straightforward. It's just a matter of parsing the text messages which are sent several times per second and extracting the time field. However, this gives Universal Coordinated Time, which is akin to Greenwich Mean Time. And we want the clock to display local time, which is only the same as GMT in the UK when daylight saving is not in effect.

Nowadays, we expect clocks to take care of things like daylight saving time. After all, modern computers and phones always show the correct local time, if set up correctly. We can do the happen to lie on opposite sides), or maybe four or more times, depending on the complexity of the shape.

So we go through each bounding line segment and test it for intersection with our imaginary line segment. This is done by computing the dot products, cross products and lengths of those vectors with reference to the signs and magnitudes of the results. This is hard to explain unless you are well-versed in vector mathematics, but it's a relatively fast method to find whether the lines intersect.

For each intersection, we increment a counter. After having considered all point pairs in the time zone boundary polygon, if the counter value is odd, we must be within that time zone and we need not consider any of the others. We then look up its rules (offset, daylight savings) and apply them to the UTC time/date to get and display the local time.

If we go through all the time zone regions and we're not within any of them, the time zone offset must be entered manually via the pushbutton interface. Alternatively, should your time zone rules change, you can override this automatic detection using the same setting to prevent the clock from showing the wrong time.

Nixie tubes: how they work

Nixie tubes work on the same principle as the simple neon indicator. A neon indicator consists of a small glass tube filled with inert neon gas and containing two metal electrodes. When a sufficiently high voltage is applied between the electrodes, the gas around the negative electrode (the cathode) ionises and envelops the electrode with an orange glow.

The voltage required for ionisation of the gas is dependent on the electrode spacing and the temperature. Typically, it is more than 80V for small neon bulbs and more than 150V for Nixie tubes. In practice, higher voltages are used, with a series resistor to limit the discharge current to a safe value.

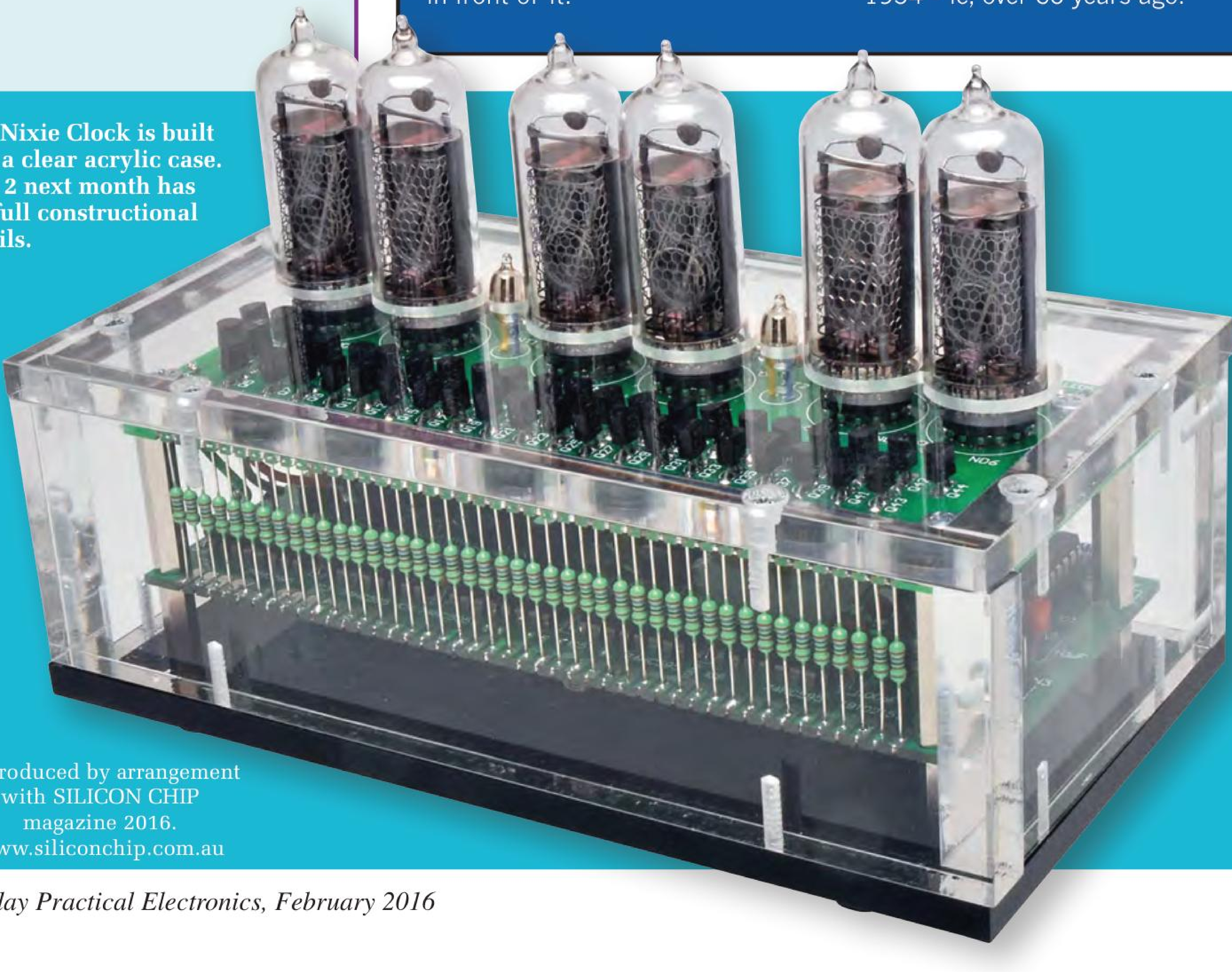
Two small neons are used in this clock design, between the hours and minutes and between the minutes and seconds tubes.

A Nixie tube has a see-through metal mesh anode at the front and 10 different shaped cathodes (0-9) behind the anode, each being terminated to a different wire lead or pin on the tube. The number-shaped cathodes are not necessarily placed in direct order behind the anode but are placed to give minimum obstruction of each digit by the ones in front of it.

The anode is connected to +HT via a current-limiting resistor and the particular cathode is pulled down to 0V when it is to be lit. By the way, 'HT' is old-timer talk for 'high tension' or high voltage.

New old stock

Nixie tubes are no longer manufactured. Instead, they are now available as 'new old' stock, originally made in either the US or the former USSR. The ones used in the Nixie Clock described in this article were made by RCA (USA) in February 1954 – ie, over 60 years ago.



The Nixie Clock is built into a clear acrylic case. Part 2 next month has the full constructional details.

Reproduced by arrangement
with SILICON CHIP
magazine 2016.
www.siliconchip.com.au

How quickly will you get a GPS fix?

When a GPS module is powered up for the first time, it starts searching for satellite signals. Normally, there are somewhere between about 10 and 14 GPS satellites overhead at any one time – however, if parts of the sky are occluded (eg, by a roof), then the receiver may not be able to pick up all the signals.

In addition to 'finding' the satellites, the receiver module has to gather the 'ephemeral' data which is slowly broadcast by those satellites. This will normally take at least half an hour. This data changes slowly, so if the receiver has a recent copy of the data, it won't need as long to get enough data to begin operation. With a 'hot start', it can be up and running in seconds.

If it has never been powered up before or if it has lost power for long enough for its RAM back-up battery/capacitor (if fitted) to discharge, it can take quite some time to get a fix. How long depends on how clear a 'view of the sky' the receiver has.

In an indoors location, some receivers will never get a fix unless they already have a relatively up-to-date version of the ephemera stored in RAM. In other words, you might find that the module will not get a fix until it has been taken outdoors for a few minutes (powered up, obviously) and then brought back inside. It may then be able to maintain a good fix with the weak signal available at that location. Sometimes, putting the module next to a window for a little while will do the trick.

This is why many GPS modules have an onboard RAM back-up battery, so they can keep track of time and ephemeral data while powered down. Some do not have this feature though – presumably, the assumption is that they are part of a battery-powered instrument and so are never without a power source.

You don't need to use a GPS module with an on-board battery in the Nixie clock. Most modules which don't have a battery will have a power pin which can be connected to a back-up power source. This may be labelled VDD_B or similar (check the data sheet). On the UP501, this is pin 5. (The UP501B has an onboard battery and pin 5 should be left unconnected).

Assuming that a 3.3V supply is suitable (true for the UP501 and probably most other modules), you can simply wire this up to pin 2 of CON3, the ICSP header. VDD_B will then be powered from the onboard 1F supercap and so the ephemera will be preserved for many hours (probably days or weeks) without mains power. The GPS module will then be able to get a fix relatively quickly when the power comes back on.

Note that one reason that the ephemera is required is that GPS time differs slightly from UTC. At the time of writing, the difference is about 12 seconds and this is due to leap seconds having been used since the GPS system was set up. So the receiver needs this data not only to get a position fix but also to report accurate time.

Note also that in some buildings you may need to keep the Nixie Clock near a window in order for it to get a good fix at all.

same thing using a GPS module since we can figure out the time zone and daylight savings rules based on the present location.

But this is a difficult problem because there are so many different rules and the various boundaries where they change are not always straight lines! We need to figure out which side of a border the unit is on to display the correct time year-round.

Basically, if you are using a GPS module for time, this is all handled automatically. The calculations are accurate to within a few tens of metres so unless you live right next to the border and are very unlucky, the time shown should be correct. If you're interested in the details of how the software does these calculations, refer to the 'Determining Local Time Using GPS' panel.

Physical layout

The Nixie Clock is built on two PCBs, with a few wires and 44 resistors connecting them together. The lower PCB has the power supply and all the control circuitry (including the GPS receiver, if fitted), while the upper PCB has the Nixie tube sockets, neon indicators, blue LEDs and most of the high-voltage transistors.

Both boards are mounted on spacers within a clear acrylic (Perspex) case to provide insulation so that you can't get a shock from the 180V Nixie anode supply. The Nixie tubes protrude through holes on the top, while the power connector and pushbuttons are accessible through holes at the rear.

We'll get to the construction of the two PCBs and the final assembly into the case in Part 2 next month.

PoLabs
For more information or software download please visit
www.poscope.com/epe
PoKeys
Connect, Control

PoKeys is a succesful story about versatile and extremely **powerful** controller.

Save your time with **fast** connectivity and **easy** configuration of advanced features.

Enjoy rare moments in life while PoKeys is taking care over your house or garden.

Take a break while PoKeys is controlling stepper motors in your **CNC** or **3D printer**.

Let PoKeys make your imagination come true using our intuitive software and plugins for Mach3/4.

Stepper motor drivers
Drive
Safest and most efficient force for your motors.

PoScope Mega1+
Measure

Do you need a really **powerful** and **portable** oscilloscope that will save your time, money and make your life with measurements **easier**?

PoScopeMega1+ is lowest power consumption USB oscilloscope, function generator and logic analyzer all-in-one available on the market.

Win a Microchip PICDEM Lab II Development Platform

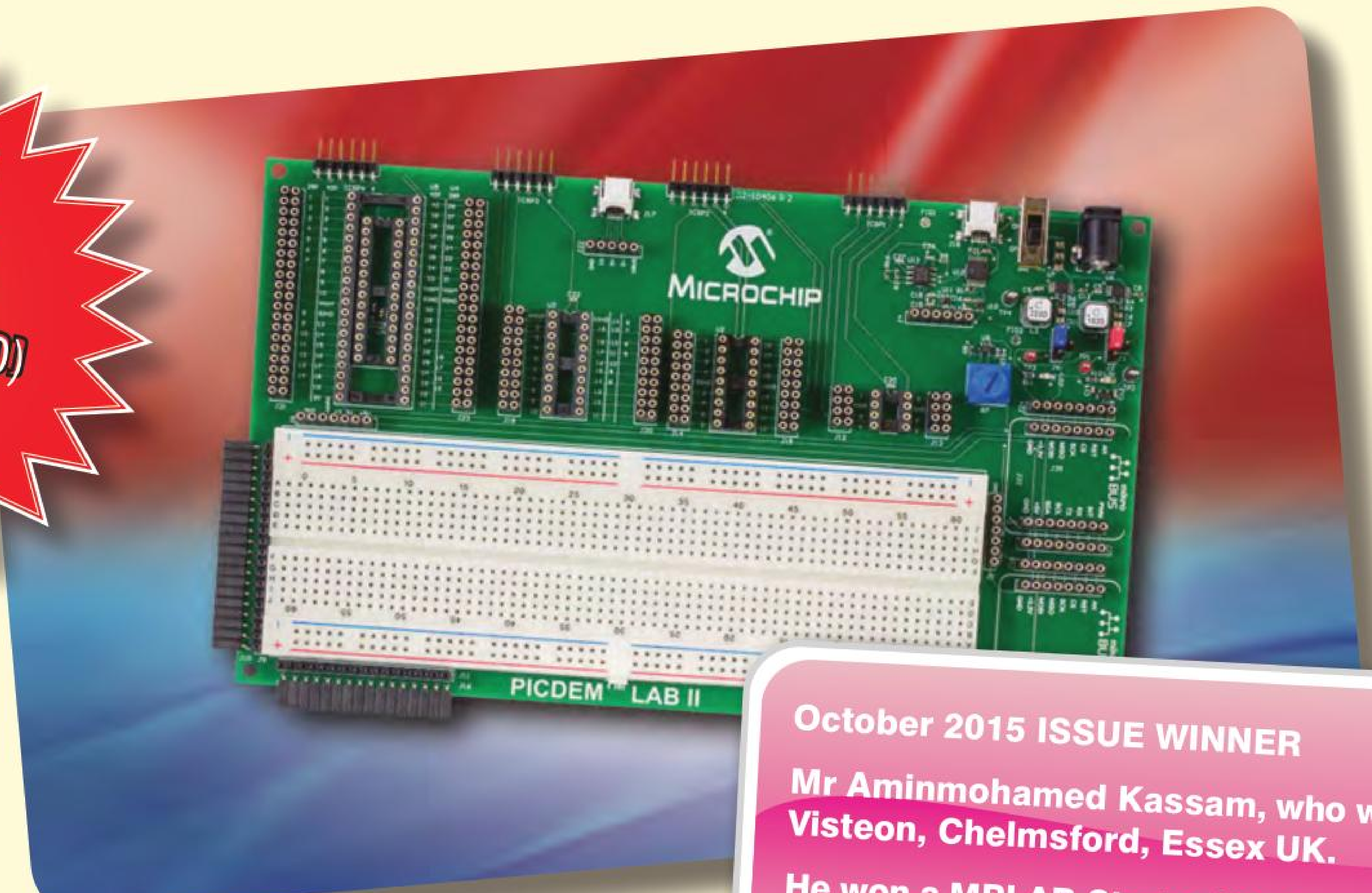
EVERYDAY PRACTICAL ELECTRONICS is offerring its readers the chance to win a Microchip PICDEM™ Lab II Development Board (DM163046). The board is a development and teaching platform for use with 8-bit PIC® microcontrollers (MCUs). At its centre, a large prototyping breadboard enables users to easily experiment with different values and configurations of analogue components for system optimisation. Several external connectors allow for user-customisable expansion, while our library of labs and application notes enrich the development experience. The PICDEM Lab II Development Board is also fully compatible with our latest software development environment.

KEY FEATURES

• Supports all 8-bit PIC MCUs from 6 to 40 pins • Programming headers and power connections for all MCU sockets • Three individual power supplies • 5V, 3.3V, variable (1.5-4.5V) • Large breadboard area for external analogue and sensor connections • External connections for industry-standard communications and expansion interfaces • Lab hardware and documentation for four labs included in the box • RS232 and Bluetooth Low Energy interfaces

The original PICDEM Lab Development Board has remained one of the most popular development tools for PIC MCUs since its introduction. Microchip has taken this concept and expanded it for 21st century embedded development. The PICDEM Lab II Development Board supports any 8-bit PIC microcontroller (6-, 8-, 14-, 18-, 20-, 28- and 40-pin footprints), and provides an expansive array of connections for programming, I/O, analogue and communications interfaces. The PICDEM Lab II Development Board will be a valuable resource to engineers across a broad spectrum of specialties, from analogue designers looking to explore the power and flexibility of MCU-based systems to engineering professors seeking a flexible and relevant teaching tool that they can add to their curricula.

WORTH
$100.00
(approx. £65.00)
EACH



October 2015 ISSUE WINNER

Mr Aminmohamed Kassam, who works at Visteon, Chelmsford, Essex UK.

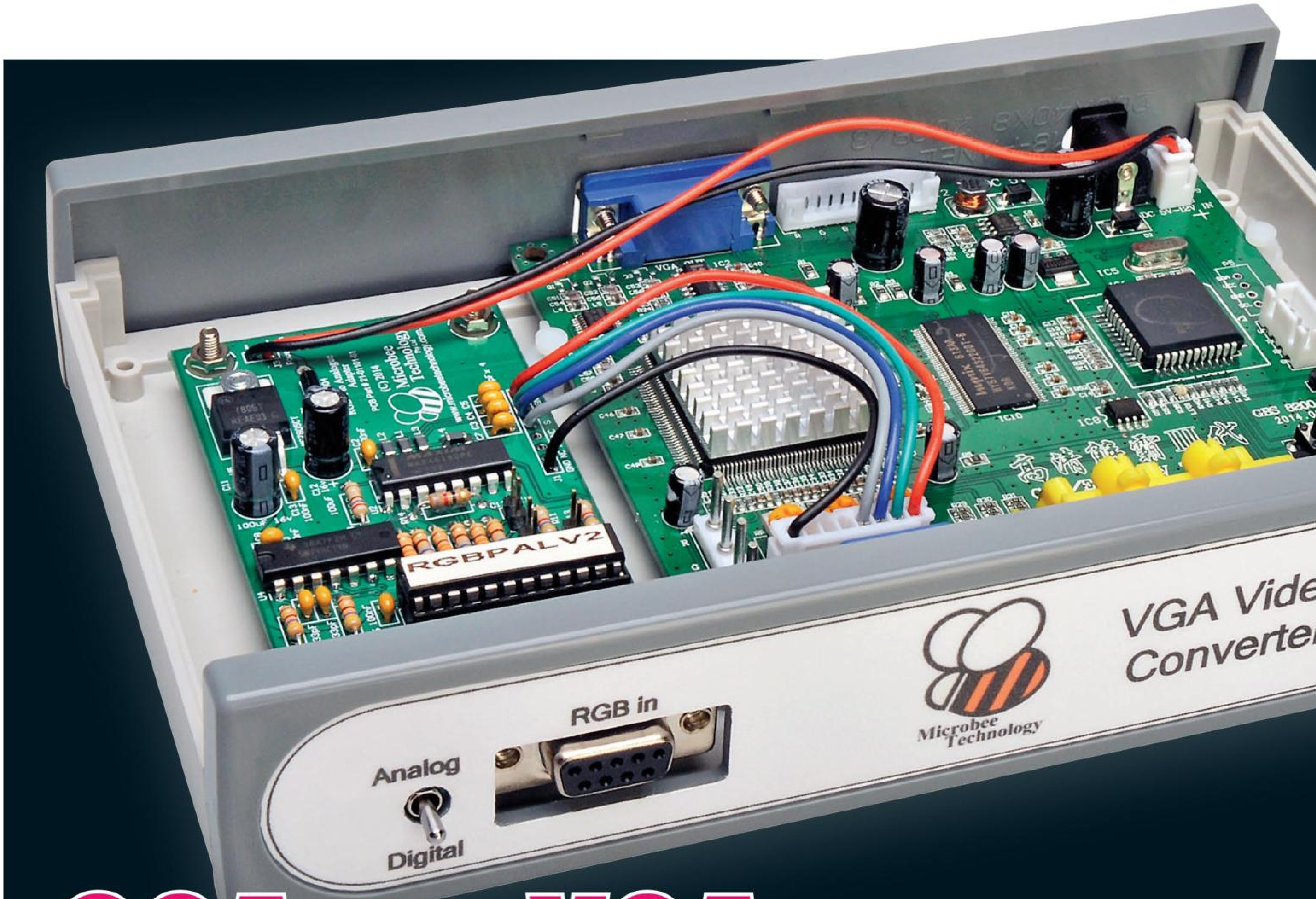
He won a MPLAB Starter Kit for PIC24F valued at £78.50

HOW TO ENTER

For your chance to win a PICDEM Lab II Development Board, visit:
http://www.microchip-comps.com/epe-picdemlab2 and enter your details in the online entry form.

CLOSING DATE

The closing date for this offer is 28 February 2016.



CGA-to-VGA Video Converter

. . . for legacy computer systems

Do you have an old Amiga, Commodore 128, Microbee, Apple or Tandy CoCo 3 computer that you would like to fire up again? Sure, it will be a nostalgia trip but you may not have a suitable CGA monitor – they were obsolete years ago! This *CGA-to-VGA Video Converter* from Microbee Technology will allow you to use any recent model LCD or CRT monitor that has a VGA input.

TINKERING WITH old computers, otherwise known as 'retro-computing', has become quite popular over the last few years for various reasons. Firing up these old machines allows you to visit a time when home computers first became affordable and widely available, back in the late 1970s and early 1980s.

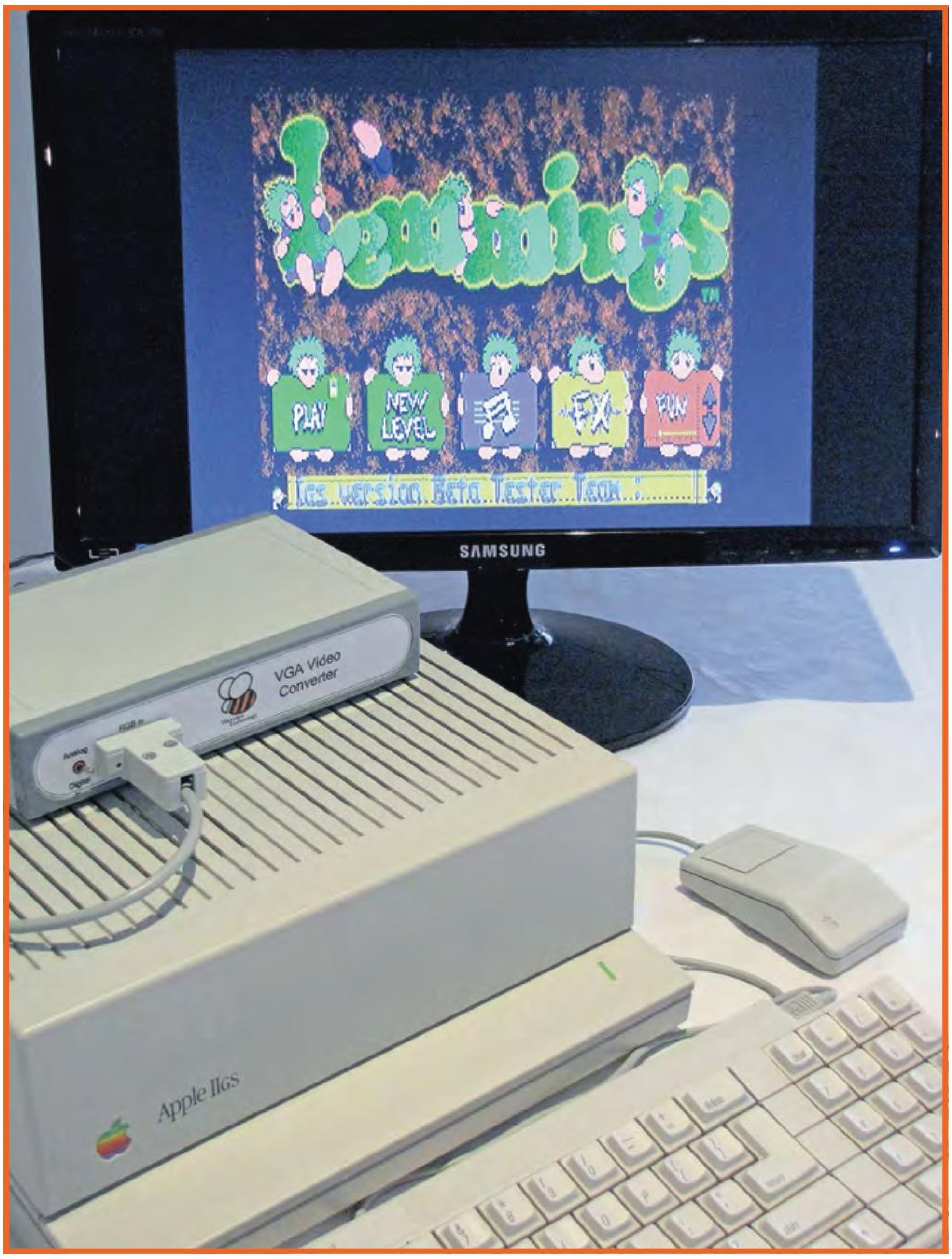
For some, this means revisiting the start of their career in electronics and computing. For others, it was the start of a love of gaming. For other groups, it was a chance to tinker with the hardware of these machines – getting the soldering iron out and adding memory chips, interfacing to external hardware, controlling relays, reading analogue signals, decoding and listening in on radio teletype and weather facsimile transmissions and so on.

By Ewan Wordsworth

Director, Microbee Technology Pty Ltd

Left: the *CGA-To-VGA Video Converter* is built into a standard ABS case and is based on a commercial video scaler board (designated the GBS-8200). It's interfaced to the computer via an RGB Intensity Board (at the lefthand end) which you assemble yourself.

Right: the unit works with virtually any PC that has a CGA video output, including the Apple IIGS, as shown here.



The list of hardware projects was endless. But now, if you want to fire up one of these old machines and obtain a full colour display, it isn't so easy unless you have a working colour monitor for your old machine stashed away in a cupboard somewhere.

Just plugging in to a VGA monitor will not work or it may only 'half work'. The complete solution is the Microbee *CGA-to-VGA Video Converter*. This kit is based around a common commercial video scaler board, the GBS-8200 v4, which is readily available via the internet. It is widely used to convert arcade machines to use VGA CRT or LCD monitors.

GBS-8200 drawbacks

The GBS-8200 scaler board takes analogue RGB signals with scan rates of 15kHz (CGA) or 21kHz (EGA) and scales the video to suit a VGA monitor with a scanning rate of 31kHz. But while the GBS-8200 board is good on its own, it does have a number of drawbacks.

First, the scaler board requires 'clean' horizontal and vertical sync signals. If these are not clean, there is likely to be display jumping and poor picture sharpness. Also, the analogue input to the GBS-8200 board does not cater for a true CGA colour output. The CGA interface standard provides digital (TTL level) RGB signals, plus an INTENSITY signal, giving eight colours with two levels of brightness; ie, 16 colours in total.

To fully implement the CGA colour set, the INTENSITY level needs to be used to scale the RGB signals to create an analogue output. Once these items are taken care of, the rest of the work is done by the GBS-8200 scaler board.

The drawbacks are overcome by adding a custom input board from Microbee – the **RGB + Intensity-to-Analog Adapter**, to give it its full description. From here on, we will refer to it as the **RGB Intensity Board**.

While this project is designed primarily for use with Microbee Premium series computers, it can also be used with a number of other older computers, including the IBM PC (and its numerous clones), Apple IIGS, Commodore 128, Amiga and Tandy CoCo 3. Other computers that have a 15kHz scan rate and either analogue or digital RGB output signals should work with this circuit as well.

Circuit details

Now refer to Fig.1 which shows the circuit details of the Microbee RGB Intensity Board. It employs two MAX4619 analogue multiplexers (IC1 and IC2), together with a PAL (programmable array logic) device (IC3). IC3 contains

Parts List

Short-Form Kit

1 Microbee double-sided PCB with plated through holes, Part No. 21-01101-01
1 SPST 90° PCB-mount mini toggle switch
4 SMD 1206 inductors, 600Ω @ 100MHz (L1-L4)
3 2-way pin headers, 0.1-inch pitch (JP1,JP2,JP3)
1 PCB-mount 90° female DB9 socket
1 24-pin DIL socket
1 M3 × 6mm screw and nut

Semiconductors

2 MAX4619 CMOS analogue switches (IC1 and IC2)
1 PAL22V10 PAL IC, programmed by Microbee (IC3)
1 74HC14 hex Schmitt trigger inverter (IC4)
1 7805 3-terminal regulator (REG1)
1 1N4004 silicon diode (D1)

Capacitors

2 100µF 16V electrolytic
5 100nF MMC
6 33pF MMC

Resistors (0.25W, 5%)

3 4.7kΩ
3 680Ω
2 470Ω
3 330Ω
1 270Ω
1 82Ω

Full Kit

1 short form kit (as listed above)
1 modified GBS-8200 video scaler board and cables
1 drilled and routed ABS case, 200 × 120 × 40mm
1 set of mounting hardware and rubber feet
1 2m-long DB9/M to DB9/M cable

Power Supply (not supplied): 7.5-12V DC @ 1A or 5V DC regulated @ 1A (see text)

Where to buy the kits

Both the short-form kit and full kit are available from Microbee Technology Pty Ltd – see www.microbeetechnology.com.au for the details. (UK purchasers need to enter address and complete details before purchase to determine postage costs.)

SAMSUNG
VGA Video Converter
RGB In
Analog
Digital
microbee
Premium PLUS+
TANDY

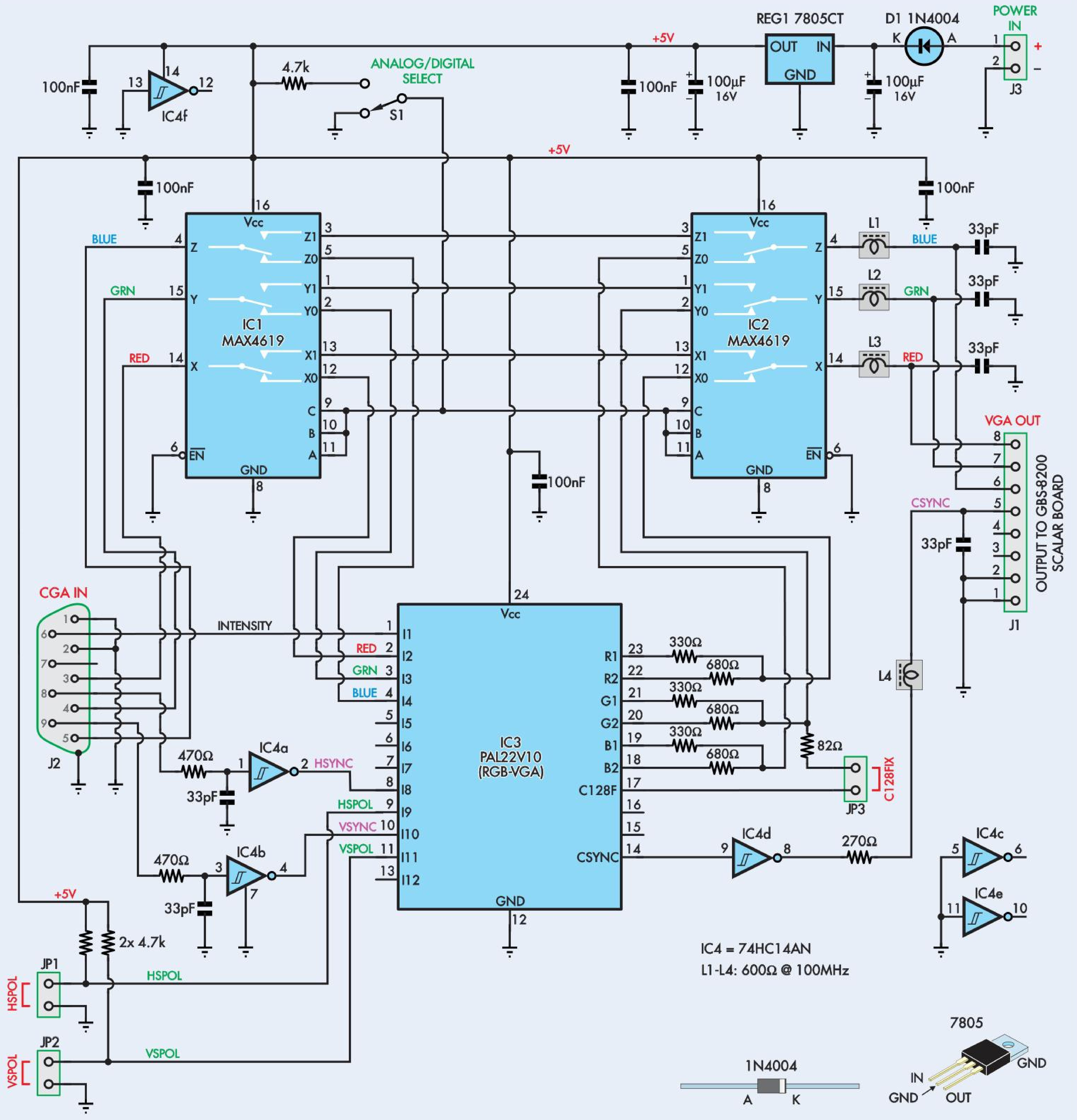
Top and above: the *CGA-To-VGA Video Converter* also works with old Microbee and Tandy CoCo 3 computers, as well as the IBM PC, Amiga and Commodore 128.

the logic that provides the digital-to-analogue conversion with the correct colour map for the CGA standard.

Switch S1 selects between the analogue and digital RGB modes by switching the two analogue multiplexers to either pass through the analogue signal or divert the digital RGB signals through IC3. The PAL (IC3) then produces two red (R1 and R2), two green (G1 and G2) and two blue (B1 and B2) outputs at pins 18-23.

These pairs of outputs are then summed via 330Ω and 680Ω resistors to give the correct analogue voltages. The load that the GBS-8200 board presents for each of R, G and B signals is 75Ω and the aforementioned summing resistors provide a video signal of 0.7V peak and drive the 75Ω loads via IC2.

The horizontal and vertical sync signals from the CGA input socket (J2) are fed through RC low-pass networks, both consisting of a 470Ω resistor and a 33pF capacitor, before being fed to Schmitt trigger stages IC4a and IC4b (74HC14AN) to square them up and feed them to the PAL (IC3). IC3 then combines the squared up HSYNC and VSYNC signals to produce a composite


REG1 7805CT
D1 1N4004
POWER IN
+5V
OUT IN GND
K A
100nF
100µF 16V
J3
4.7k
ANALOG/DIGITAL SELECT
S1
IC4f
IC1 MAX4619
IC2 MAX4619
Vcc
GND
Z1 Z0 Y1 Y0 X1 X0
C B A
EN
BLUE
GRN
RED
L1
L2
L3
L4
33pF
VGA OUT
OUTPUT TO GBS-8200 SCALAR BOARD
CSYNC
J1
CGA IN
J2
INTENSITY
IC3 PAL22V10 (RGB-VGA)
C128F
330Ω
680Ω
82Ω
JP3
C128FIX
IC4a
HSYNC
IC4b
VSYNC
HSPOL
VSPOL
470Ω
IC4d
270Ω
IC4c
IC4e
2x 4.7k
JP1
JP2
IC4 = 74HC14AN
L1-L4: 600Ω @ 100MHz
1N4004
7805
IN
GND
OUT

RGB INTENSITY BOARD (MICROBEE TECHNOLOGY)

Fig.1: the circuit for the add-on RGB Intensity PCB. IC1 and IC2 are MAX4619 analogue multiplexers which switch the RGB signal lines, while IC3 is a PAL (programmable array logic) device which performs digital-to-analogue conversion to provide the correct colour map for the CGA standard.

sync output which is fed to Schmitt trigger stage IC4d. Sync signals for CGA are normally positive-going but some monitors require negative-going sync signals. Jumpers JP1 and JP2 cater for this.

Finally, the reconstituted RGB and combined sync signals are passed through individual LC low-pass filters which each consist of a surface mount inductor (L1-L4) and a 33pF capacitor. Each of these SMD inductors has an impedance of 600Ω at 100MHz.

Jumper JP3 (C128FIX) corrects the colour output for a Commodore 128 computer – see accompanying panel.

Power for the RGB Intensity Board comes from the GBS-8200 scaler board and this is fed in via reverse polarity protection diode D1. A 100µF electrolytic capacitor then filters the output from D1, which is then fed to 7805 3-terminal regulator REG1 to derive a 5V supply rail.

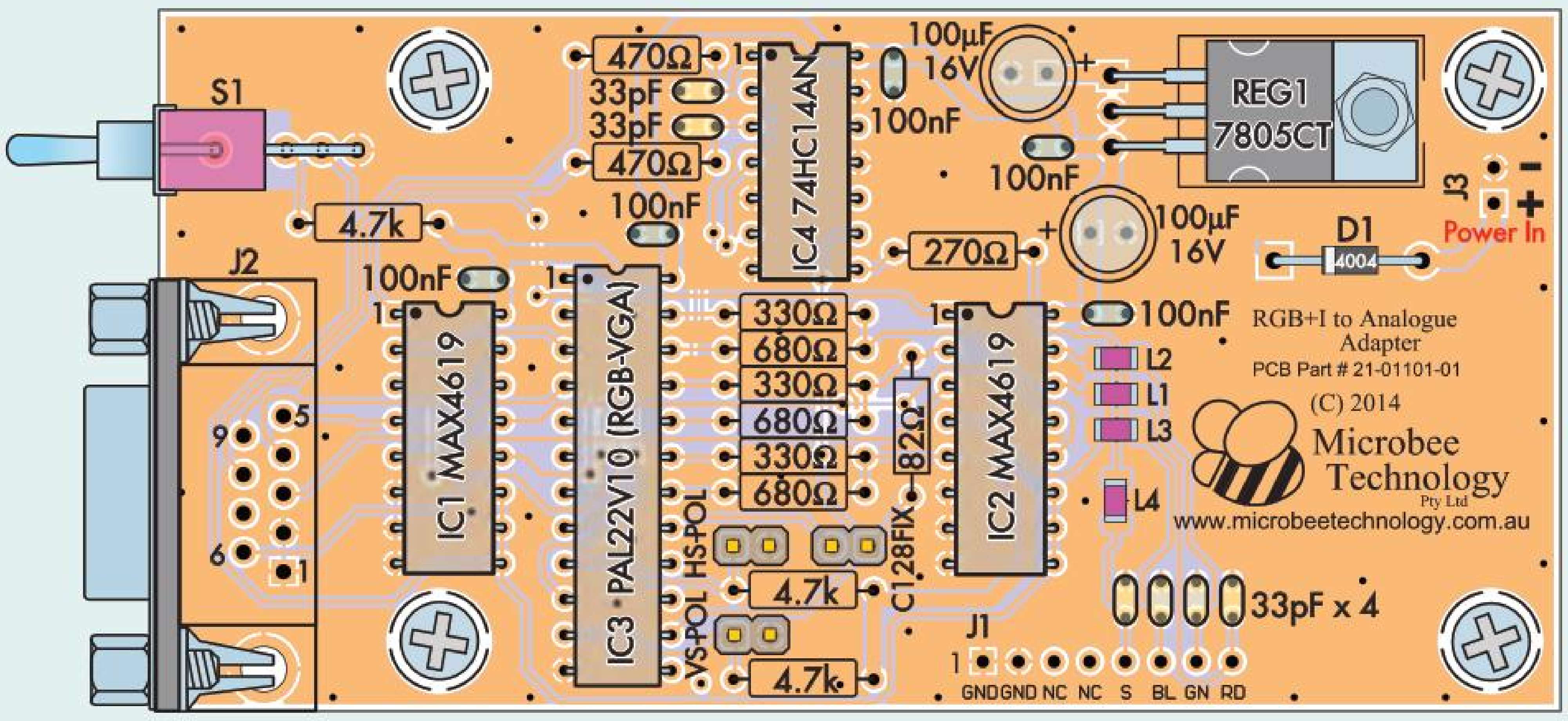
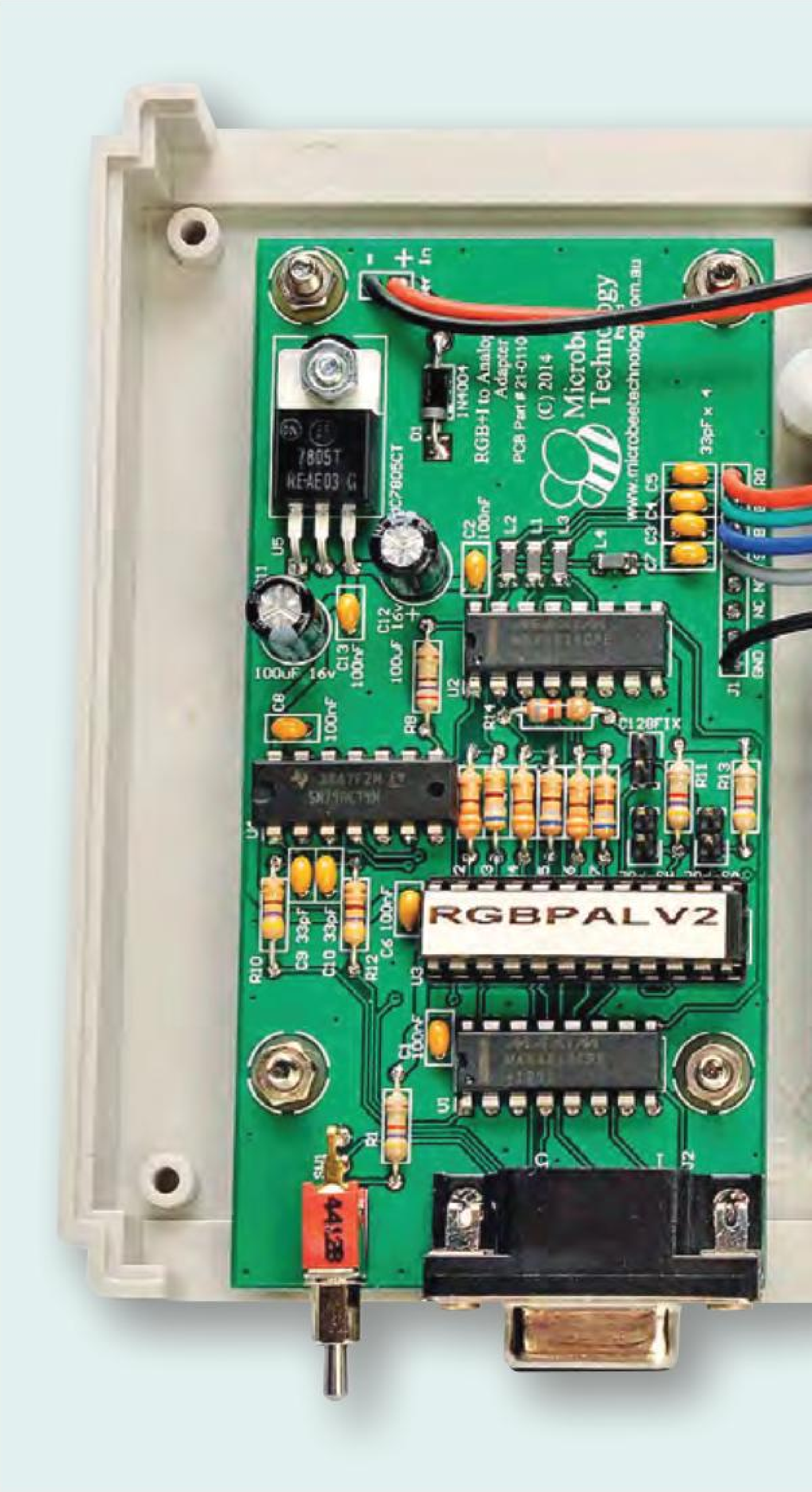

S1
470Ω
33pF
33pF
470Ω
4.7k
100nF
IC4 74HC14AN
100nF
100µF 16V
REG1 7805CT
100nF
J3
−
+
Power In
270Ω
100µF 16V
D1
4004
J2
100nF
IC1 MAX4619
IC3 PAL22V10 (RGB-VGA)
330Ω
680Ω
330Ω
680Ω
330Ω
680Ω
82Ω
C128FIX
HS-POL
VS-POL
4.7k
4.7k
IC2 MAX4619
100nF
L2
L1
L3
L4
RGB+I to Analogue Adapter
PCB Part # 21-01101-01
(C) 2014
Microbee Technology Pty Ltd
www.microbeetechnology.com.au
33pF x 4
J1
GND GND NC NC S BL GN RD
9
5
6
1

Fig.2: follow this parts layout diagram to build the RGB Intensity Board. Its J1 output is connected to the GBS-8200 scaler board via a 5-way cable fitted with a header socket (see photo at right), while the power supply inputs are connected to this board via a 2-way cable.



Construction

Construction is straightforward, with all parts mounted on a double-sided plated-through PCB measuring 100 × 50mm. Fig.2 shows the layout.

Start with the resistors and capacitors, then install inductors L1-L4. These inductors are supplied as surface-mount parts on a strip of 8mm-wide tape and it's just a matter of peeling the tape off the backing to remove them. To install them, first melt a small amount of solder onto one pad at the component location. That done, hold the inductor with tweezers, then reheat the solder and slide the inductor into place. You can then solder the other end of the device to its pad.

Next, the front-panel DB9 connector and the switch can be installed, followed by the 24-pin DIL socket for IC3. Take care to ensure that the socket is orientated correctly, ie, notched end towards the top edge of the PCB.

If you decide to power both the GBS-8200 and the adapter board from 5V DC, then regulator REG1 should be omitted. **In that case, it will be necessary to install a link between REG1's vacant input and output pads on the PCB. D1 must also be replaced with a link, but watch the supply polarity.**

Alternatively, if you don't have a regulated 5V DC supply, then a supply of 7.5-12V DC is recommended and REG1 (and D1) must be installed to provide 5V for the adaptor board. It's just a matter of bending REG1's leads down through 90° exactly 6mm from its body before fitting it in place. Its metal tab is then secured to the PCB using an M3 × 5mm machine screw and nut, *after* which its leads are soldered and trimmed.

Be sure to fit diode D1 with the correct polarity, ie, banded end towards the 100µF capacitor.

Commodore 128: the C128FIX jumper option

The Commodore 128 has an 80-column mode that outputs RGB+I digital video on a standard CGA 9-pin D-connector. The colour set is almost identical to the normal CGA colour set, with the exception of dark yellow, which appears on Commodore monitors as brown.

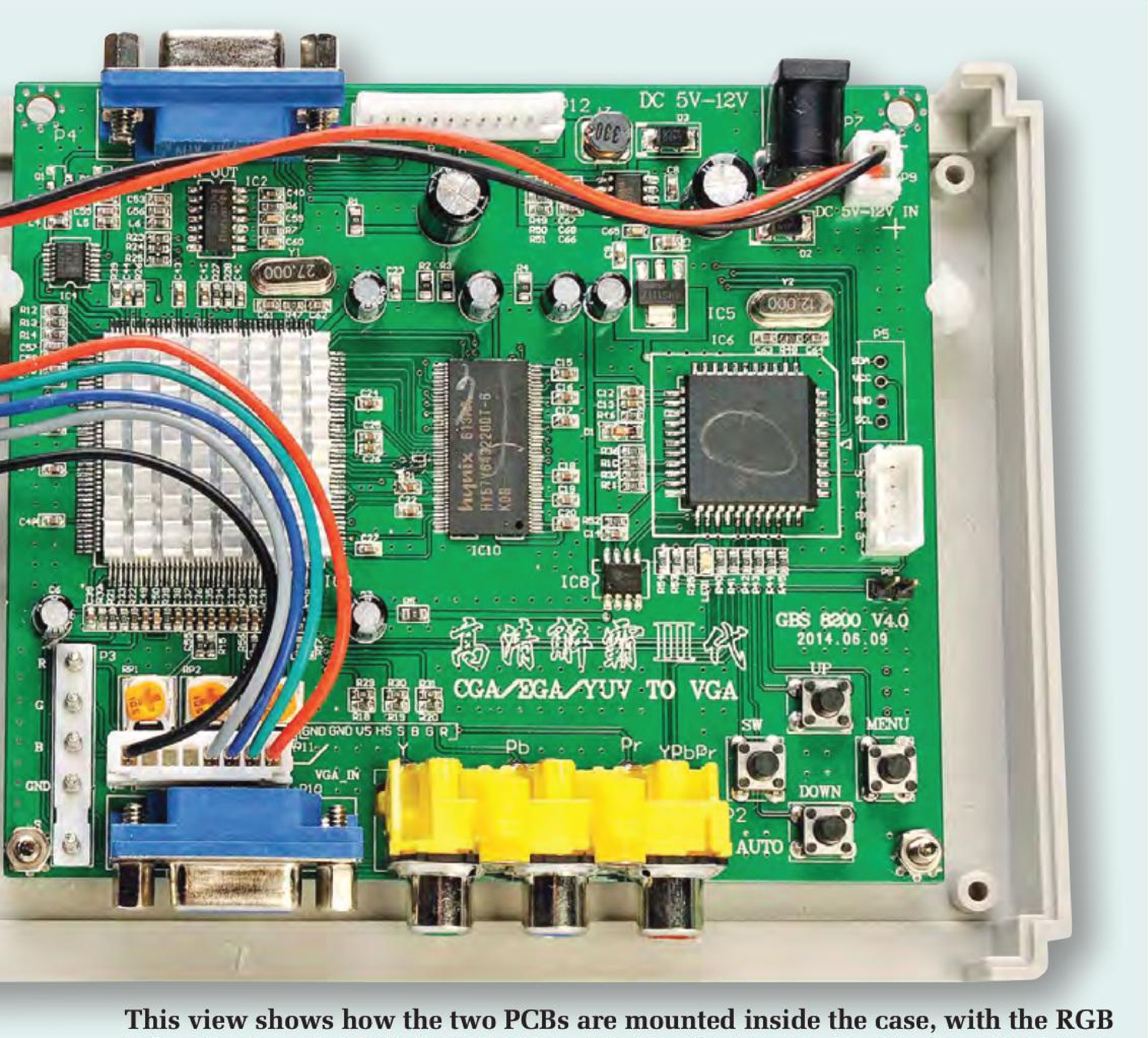
For the purist who wants to represent this colour correctly, the C128FIX jumper should be fitted. Logic inside the PAL (IC3) then pulls pin 17 of this IC low when ever this colour combination is detected. This pin in turn pulls the green level lower via an 82Ω resistor, creating a brown colour instead of yellow at the RGB output.

Table 2: Capacitor Codes

Value	µF Value	IEC Code	EIA Code
100nF	0.1µF	100n	104
33pF	NA	33p	33

Table 1: Resistor Colour Codes

☐	No.	Value	4-Band Code (1%)	5-Band Code (1%)
☐	3	4.7kΩ	yellow violet red brown	yellow violet black brown brown
☐	3	680Ω	blue grey brown brown	blue grey black black brown
☐	2	470Ω	yellow violet brown brown	yellow violet black black brown
☐	3	330Ω	orange orange brown brown	orange orange black black brown
☐	1	270Ω	red violet brown brown	red violet black black brown
☐	1	82Ω	grey red black brown	grey red black gold brown



This view shows how the two PCBs are mounted inside the case, with the RGB Intensity Board at left. Note that the VGA and component video inputs at the front of the scalar board are not used and are 'blanked off' by the front panel.

The two MAX4619 ICs (IC1 and IC2) can now be fitted (watch their orientation) and the power supply cable soldered to the J3 position (red lead to positive, black to negative). That done, solder the RGB input cable (supplied with the GBS-8200 board) to the J1 position with the black (GND) wire at the pin 1 end. The accompanying photos show the wiring details.

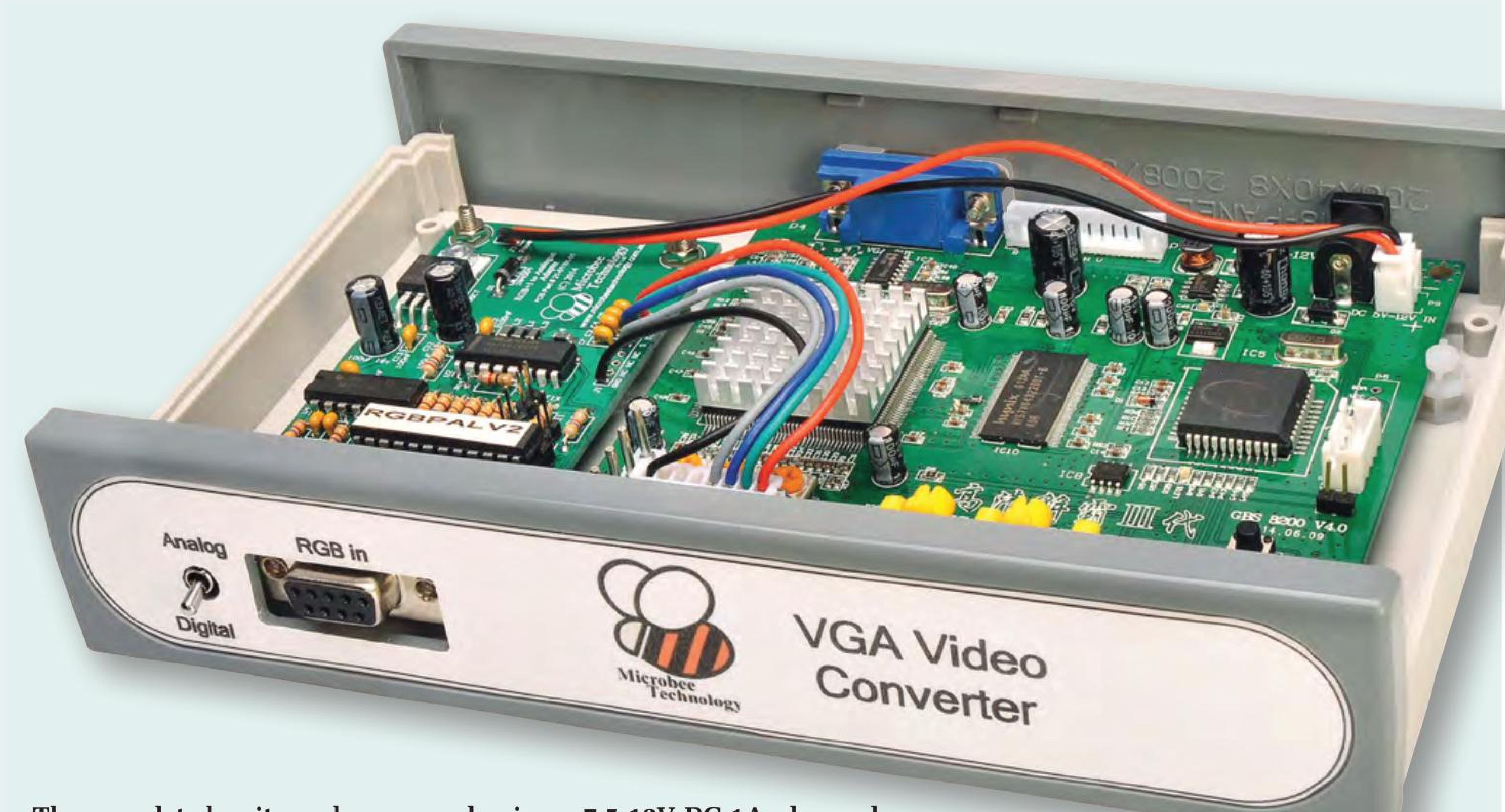
Note that only five wires are needed, ie, for pin 1 and pins 5-8. The supplied cable also has a yellow wire on pin 3 and this should be removed.

If you are fitting the boards into the supplied case, you can trim the RGB cable to around 100mm. As always, check your work before applying power. In particular, look for shorts and poor solder joints and check the orientation of all polarised components.

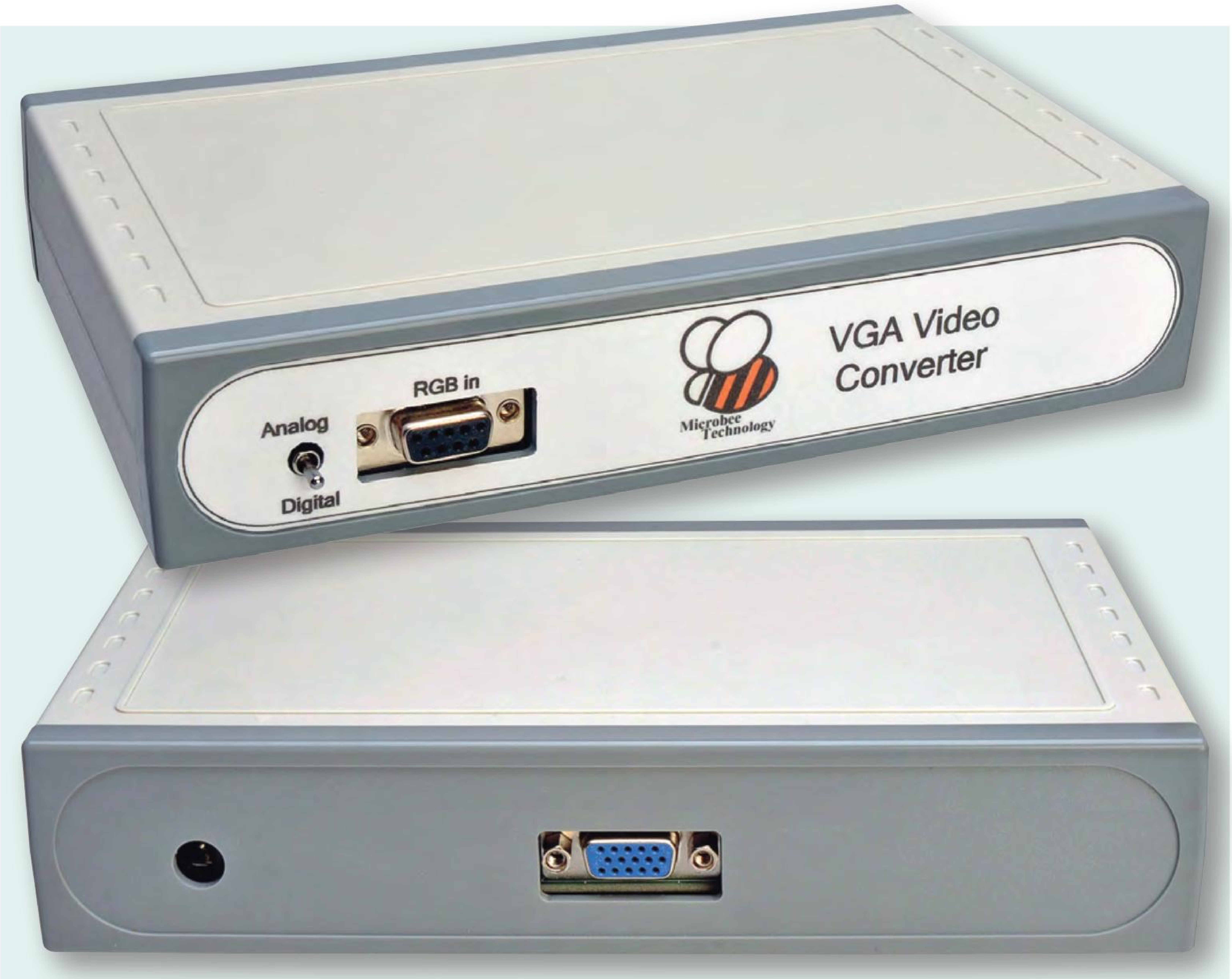
Getting it going

As stated, the digital mode converts a true CGA digital input (RGB + Intensity) to the proper CGA colour map. This is the mode that's used for the Microbee Premium, Premium Plus and 256TC models, along with regular IBM PCs and numerous other computers.

The analogue mode allows the unit to be used with computers that have true analogue outputs, such as the Commodore Amiga (the converter has



The completed unit can be powered using a 7.5-12V DC 1A plugpack or a well-regulated 5V DC supply (see text). It's just the thing for getting that old 'retro' computer going with a recent-model VGA LCD (or CRT) monitor.



The completed unit is simple to hook up – all you have to do is connect your computer to the CGA input, connect the VGA output on the rear panel to a suitable monitor and connect a power supply. Note that it's necessary to install the C128FIX jumper on the RGB Intensity Board to get the correct colours from a Commodore 128 computer (see panel).

been tested with the Amiga and works brilliantly!).

Normally, the unit works with positive TTL level HSYNC and VSYNC as the timing signals. If you strike sync problems with an odd-ball system, try installing jumpers on the VS-POL and HS-POL headers. The unit will also work with a composite sync signal.

Final assembly

Once you have the unit working (it's just a matter of hooking it up to a computer and monitor and trying it out), you can mount the boards in the case which is supplied pre-drilled and routed. The two boards mount on M3 × 6mm tapped nylon spacers and are secured using M3 × 16mm screws and nuts. In addition, two 'side-mount' nylon stand-offs are used to support the rear of the GBS-8200 scaler board (see photos).

These side-mount stand-offs are necessary because the rear mounting holes in the GBS-8200 PCB are unusable due to the case design.

Once the PCBs are in place, the top of the case can be fitted and the front and rear panels snapped into place to lock the case together.

That's it – the *CGA-to-VGA Video Converter* is complete.

Modifications to the GBS-8200 board

While developing this project, we detected a fault in the signal output from the GBS-8200 scaler board under certain conditions. Intermittently, and mostly when the board was cold, there would be 'snow' on the video output.

Apparently, this is a common fault with the GBS-8200 and appears to be a result of omitting damping resistors in the SDRAM interface and poor calibration of the SDRAM timing. As a result, Microbee has modified the GBS-8200 scaler boards supplied with their kits for optimal output.

Finally, we recommend setting the VGA monitor to a resolution of 1024 × 768 pixels and setting the sharpness close to maximum.

Reproduced by arrangement
with SILICON CHIP
magazine 2016.
www.siliconchip.com.au

Gold standard

Ian Bell

Describing an engineering subject like electronics with depth, clarity and a minimum of mathematics is never easy, but these are just some of the claims to fame for the long-awaited third edition of *The Art of Electronics* by Horowitz and Hill – Ian Bell reviews this refreshed classic for *EPE*

THE ART OF ELECTRONICS (AoE) by Paul Horowitz and Winfield Hill – often simply called 'Horowitz and Hill' – was my favourite electronics book when I was a student. It had comprehensive coverage of both analogue and digital electronics, but that was true of several texts aimed at electronic engineering undergraduates. What made it different was that it was written in a less formal, more enjoyable style and it was more focused on actually explaining practical design and development, rather than just presenting mathematical circuit analysis. The insights, tips and tricks *AoE* provided helped me fill the gaps between theory and actually designing things that worked. The point the authors were making with their approach was not that the mathematics in traditional texts is unnecessary, but that, first, it is not the whole story (hence perhaps the 'Art' in the title) and, second, not everyone studying and practising electronics always needs mathematical detail.

I still have a copy of the first printing of the first edition paperback (*AoE1*), dated 1980. Its well-thumbed state bearing testimony to its heavy use. The second edition (*AoE2*), which I also own, was published in 1989. It is regarded by many as the classic textbook on electronics, with over a million copies of the first two editions sold worldwide. Of course, time takes its toll and rapid advances in technology meant that in recent years, sections of the second edition looked very dated, although some parts remained useful.

Long anticipated

A third edition had been anticipated for several years, with comments from the authors concerning progress with the book appearing on various web forums from time to time. According to Paul Horowitz in an interview with Limor Fried of Adafruit (May 2015) the third edition was originally due in 1994. So it was a very long wait, but finally *AoE3* was published by Cambridge University Press in March 2015 as a large, weighty 1219-page hardback with a gold cover, presumably designed to express *AoE's* classic status. The fifteen chapters of the new volume cover foundations, bipolar transistors, field-effect transistors, operational amplifiers, precision circuits, filters, oscillators and timers, low-noise techniques, power regulation, digital electronics, programmable logic devices, logical interfacing, digital meets analogue, computers, controllers, and data links and microcontrollers. There are also sixteen appendices. And finally, a detailed index – a good index is of course important in a book that is likely to be used for reference.

Student Manual

There is more to come; the website for the book at **artofelectronics.net** states that a new third edition *Student Manual*, called *Learning the Art of Electronics – A Hands-on Approach* is in preparation (authors Tom Hayes and Paul Horowitz). The *AoE* website currently indicates publication before the end of 2015, but Amazon UK currently have it listed for April 2016. There are also plans to publish another companion book called *The Art of Electronics: The x-Chapters*, which will cover more advanced material on passive components, bipolar transistors, FETs, op amps, power control and power supplies. These chapters are referenced in the current *AoE3* text, which will be bit frustrating until they get published.

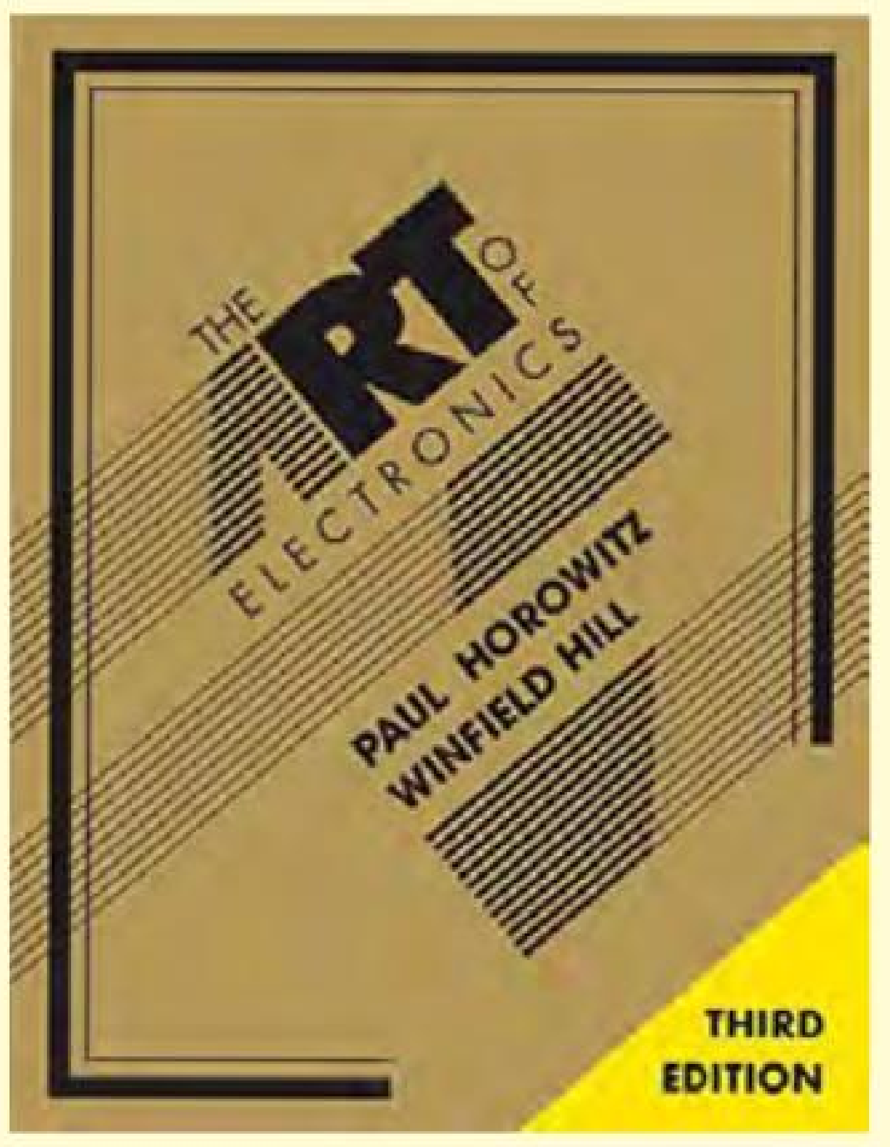
Full revision

AoE3 is a lot more than just a few tweaks to *AoE2* to update it. The larger size and smaller typeface means that it contains a lot more material and there have been significant changes to the structure of the book since the second edition; some chapters have gone and new ones have appeared. The chapter on precision circuits and low noise techniques has split into two separate chapters. These form possibly the best part of the book for anyone with an interest in analogue circuit design. As might be expected, the coverage of digital electronics has changed dramatically with a significant amount of new material covering topics such as microcontrollers and their peripheral circuits/ICs, programmable logic, hardware description languages, logic interfacing and digital buses and data links. The microcontrollers chapter provides several design examples, with simplified schematics and pseudocode to outline the software operation; this will be useful for anyone starting to learn to develop their own designs. The coverage of power regulation, power switching, and switched power supplies has also significantly increased, reflecting the significant growth in switch-mode power supply technology since *AoE2* was published.

One thing that has gone, that I enjoyed in the previous editions, are the 'bad circuits' – figuring out why these circuits were wrong was a fun way to test your understanding. Fortunately, they have not disappeared completely, as they are now on the *AoE* website. The website also provides errata for the book (which readers can contribute to), links to author interviews, news on future publications and the promise of a SPICE model library.

Recommended

If you are a hobbyist or maker who wants to acquire or improve a well-rounded knowledge of electronics then *AoE* is an ideal book for you. It starts from the very basics of voltage, current and resistance without getting heavily dependent on physics theory or mathematics, and proceeds to cover a huge variety of interesting topics. For electronic engineering students, *AoE* will not cover all the mathematics you have to study, but it will help you develop the intuitive understanding, which will make it easier to put the maths in context, and it will be invaluable when you do practical work for design projects. *AoE* brilliantly conveys its authors' enthusiasm and experience of practical engineering and is an inspiring read. Many people have described the earlier editions as the best book on electronics, so *AoE3* had a lot to live up to; fortunately, it does not disappoint. It deserves its gold cover.

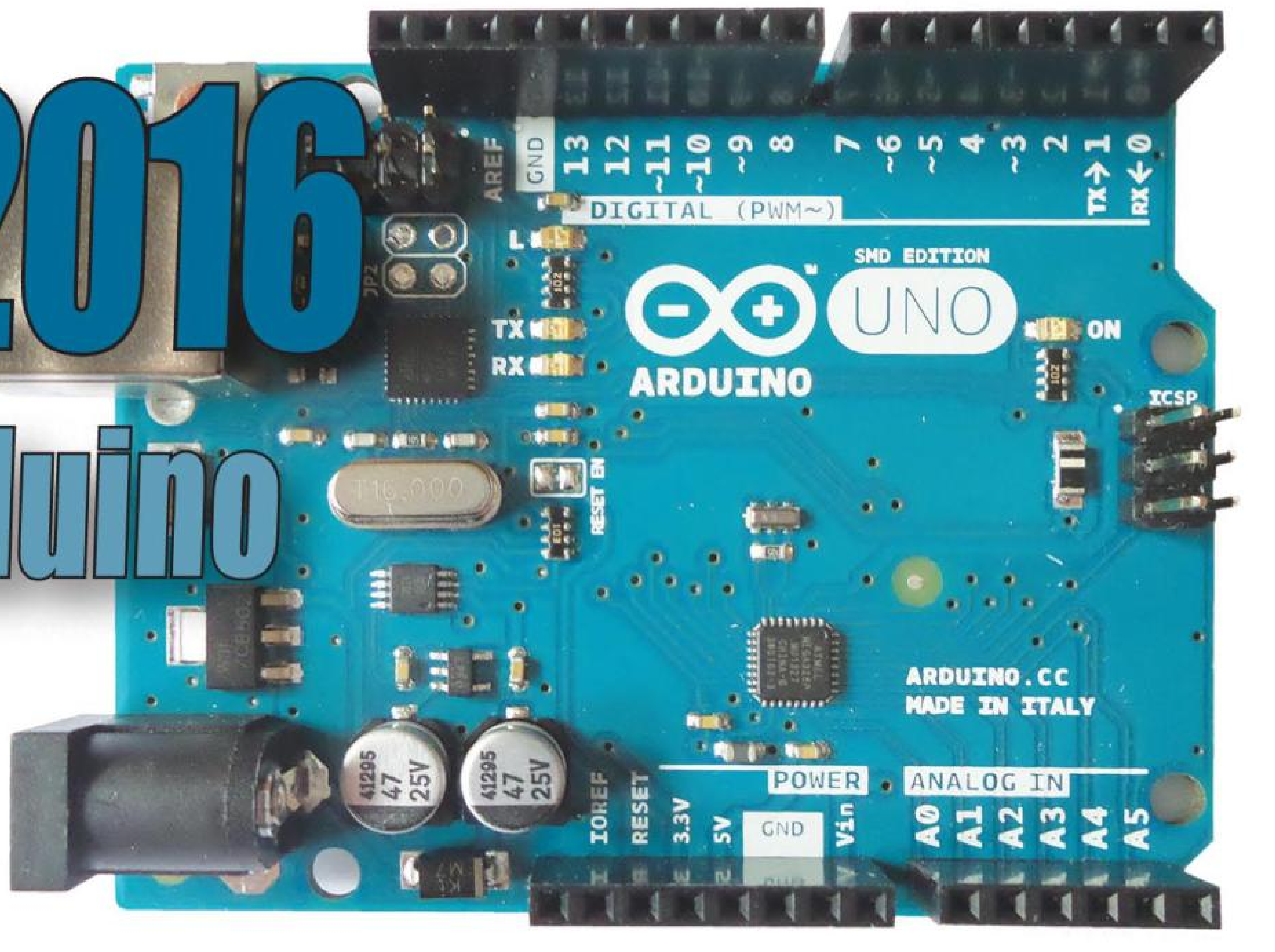


Art of Electronics
Paul Horowitz and Winfield Hill
Third Edition, 2015
Cambridge University Press
ISBN 978-0-521-80926-9

Teach-In 2016

Exploring the Arduino

Part 1: Introduction



by Mike and Richard Tooley

Welcome to *Teach-In 2016 – Exploring the Arduino.* This exciting new series has been designed for electronics enthusiasts who want to get to grips with the immensely popular Arduino microcontroller, as well as coding enthusiasts who want to explore hardware and interfacing. So, whether you are considering what to do with your Arduino, or maybe have an idea for a project but don't know how to turn it into reality, our new *Teach-In 2016* series will provide you with a one-stop source of ideas and practical information.

The Arduino offers you a remarkably effective platform for developing a huge variety of projects; from operating a set of Christmas tree lights to remotely controlling a robotic vehicle through wireless or the Internet. *Teach-In 2016* is based around a series of practical projects with plenty of information for you to customise each project to meet your own requirements and, while each project builds into a module that's self-contained and useful in its own right you will be able to combine them together in many different ways in order to build more complex systems that can be used to solve a wide variety of home automation and environmental monitoring problems. To this end, we will be introducing topics such as RF technology, wireless networking and remote Web access.

The Arduino offers a handy solution to a wide range of problems and applications. It has a very modest price tag and a complete stand-alone microcontroller system should typically cost less than about £30, making the Arduino a highly cost-effective solution to a wide range of practical problems.

This series will teach you about:

- *Programming* – introducing you to the Arduino's simple yet powerful integrated development system (IDE) and the C programming language that you will use to develop your coding skills and confidence
- *Hardware* – learn about a wide range of components and circuits that are used to interface microcontrollers to the real world
- *Microcontrollers* – letting you get to grips with Arduino hardware and software, and helping you understand how they work together
- *Communications* – showing you how to connect your Arduino to a PC, other Arduino devices and to a network for remote control and data logging using radio, Wi-Fi and the Internet.

So, what's coming up? Regular features of *Teach-In 2016* will include:

- *Arduino World* – this is where we take a look at a wide range of Arduino accessories, including shields, breadboards, prototyping boards, bus extenders, network and Wi-Fi adapters, and software simulators. We will also help you build your Arduino bookshelf with a selection of recommended books and other publications.
- *Coding Quickstart* – a short feature devoted to specific programming topics, such as data types and structures, arrays, processing user input and using library modules. We aim to get you up and running with C programming on the Arduino in the shortest possible time!
- *Get Real* – the main topic for each part will be a project that explores a particular use or application of the Arduino and that builds into a handy gadget in its own right. Projects will include a battery monitor, continuity checker, digital thermometer, diode/transistor checker, security alarm, electronic game, reaction timer and a remote data logger.
- *Arduino Workshop* – each part of our series will deal with a particular aspect of using the Arduino, including characteristics and features of different versions, hardware architecture, I/O facilities, power requirements and power sources, ports and interfacing, and using serial communications.

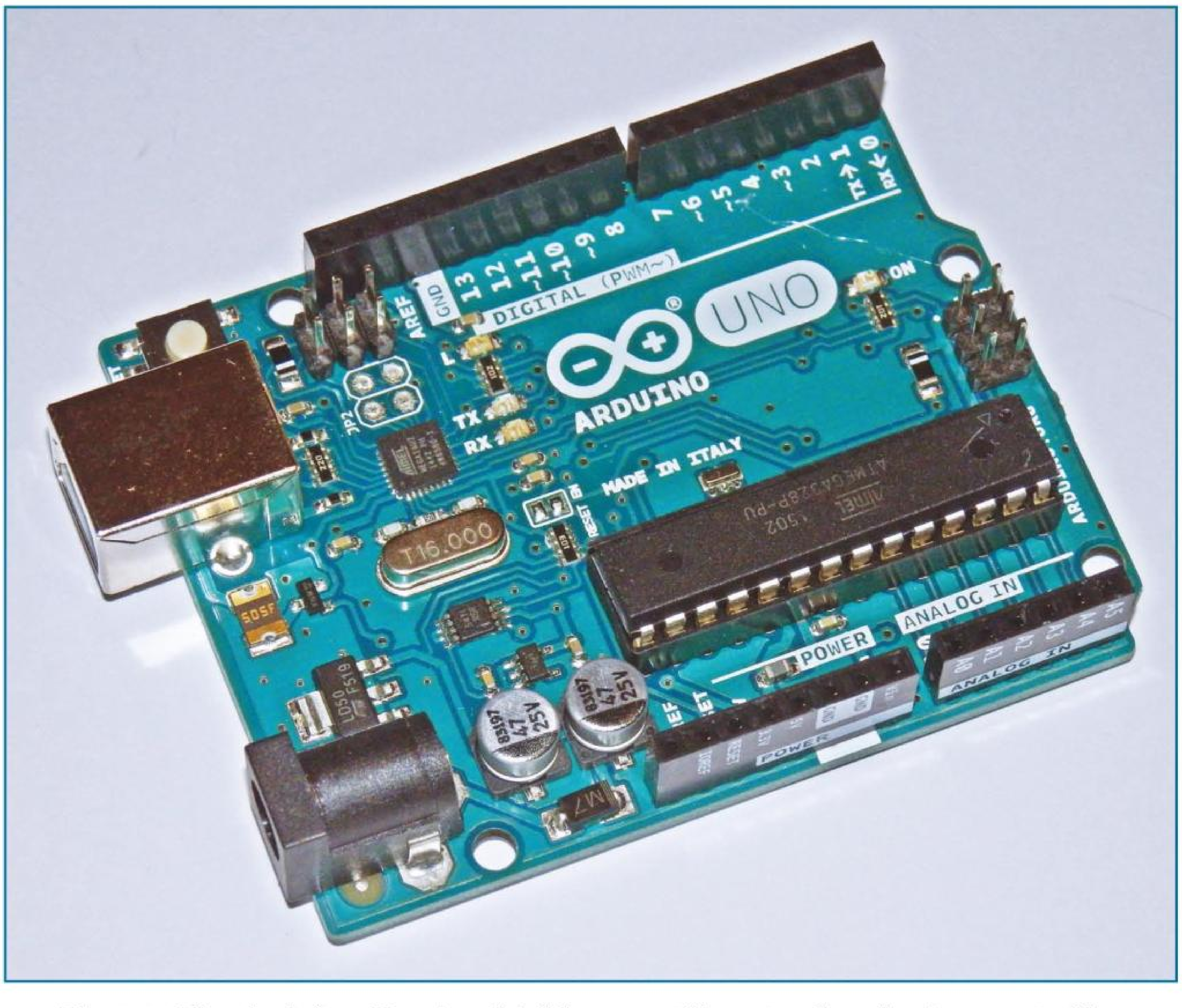


Fig.1.1. The Arduino Uno is a highly versatile entry-level microcontroller

What will I need?

To get the best out of our series you will, of course, need access to an Arduino. We recommend that you get started with the immensely popular Arduino Uno. You can get hold of one of these at very modest cost from a variety of sources (see *Introducing the Arduino*). You will also need a laptop or desktop computer with either Windows or Linux on which to develop your code. Your computer will need to have a spare USB port and you will also need a standard USB A-to-B cable.

This month

In this month's *Teach-In 2016*, we will take a first look at the Arduino, explaining why it has become so popular. *Arduino Workshop* deals with installing and running the Arduino's simple but powerful integrated development environment (IDE), while *Coding Quickstart* introduces the different types of data that you will encounter in an Arduino environment. *Get Real* deals with interfacing switches and LEDs to the Arduino's digital I/O ports and provides some simple example 'sketches' to get you started with C coding. Finally, *Arduino World* introduces the flexible and easy-to-use Arduino Simulator developed by Stan Simmons at Queen's University ECE. This brilliant free software will allow you to experiment with a virtual Arduino Uno – even if you don't have the real thing!

Introducing the Arduino

The first Arduino was developed over ten years ago by the Interaction Design Institute of Ivrea, based near the Italian city of Turin. The original aim of the project was to provide students with a simple yet powerful platform on which to develop interactive systems. Since then, the Arduino's hardware and software have evolved on a continuous basis, but the idea behind the Arduino has essentially remained the same. Today, the Arduino has become a highly effective platform for anyone needing a low-cost microcontroller suitable for use in a very wide range of applications.

With only a few exceptions, members of the Arduino family (together with a multitude of clones and compatible microcontroller boards) are all based on the popular range of chips developed and manufactured by Atmel. The ATmega328 is the most commonly used device, a powerful 8-bit general purpose RISC-based CMOS microcontroller with 32 Kbytes of built-in flash memory.

Members of the Arduino family include the Uno, Leonardo, Due and Micro models. In addition, there's a wide variety of low-cost clones and compatibles that emulate the features of each of their original Arduino counterparts. Currently, Uno clones can be obtained from Chinese suppliers at a cost of a little over £3 with free postage – good news for anyone working on a tight budget. At this point it's important to note that genuine Uno boards are invariably marked with the official Arduino logo. Low-cost clones can work well and provide you with a system that is extremely cost-effective, but in more critical applications there's a need to ensure the highest level of software and hardware compatibility and it can be well worth investing in an original and genuine version. We will explore this in greater detail in a future part of *Teach In 2016*.

Parameter	Detail
Microcontroller	ATmega328P
Clock speed	16MHz
Flash memory	32KB *3
Static RAM (SRAM)	2KB
EEPROM	1KB
Supply voltage	5V
Recommended DC input voltage range	7V to 12V *2
Digital I/O pins	14
Digital I/O pins available for PWM output	6 *1
Analogue input pins	6
Max. DC current output per pin	20mA
Max. DC current available from 3.3V supply	50mA
Dimensions	68.6 × 53.4mm
Weight	25g

Table 1.1 Technical specifications for the Arduino Uno ***(*Notes: 1. 512 bytes are used for the bootloader, 2. Maximum DC input voltage is 20V, 3. See text)***

The Arduino Uno

The entry-level Uno contains virtually everything that you need to implement a complete microcontroller system. The only additional items are a power source and a standard A-to-B USB cable for programming. The Uno will operate quite happily from nothing more than a standard 9V PP3 battery, making the microcontroller ideal for use in stand-alone applications where there's no mains supply available. Alternatively, the Uno can derive its power from an external DC supply of nominally 9V or via a USB cable and a powered USB port.

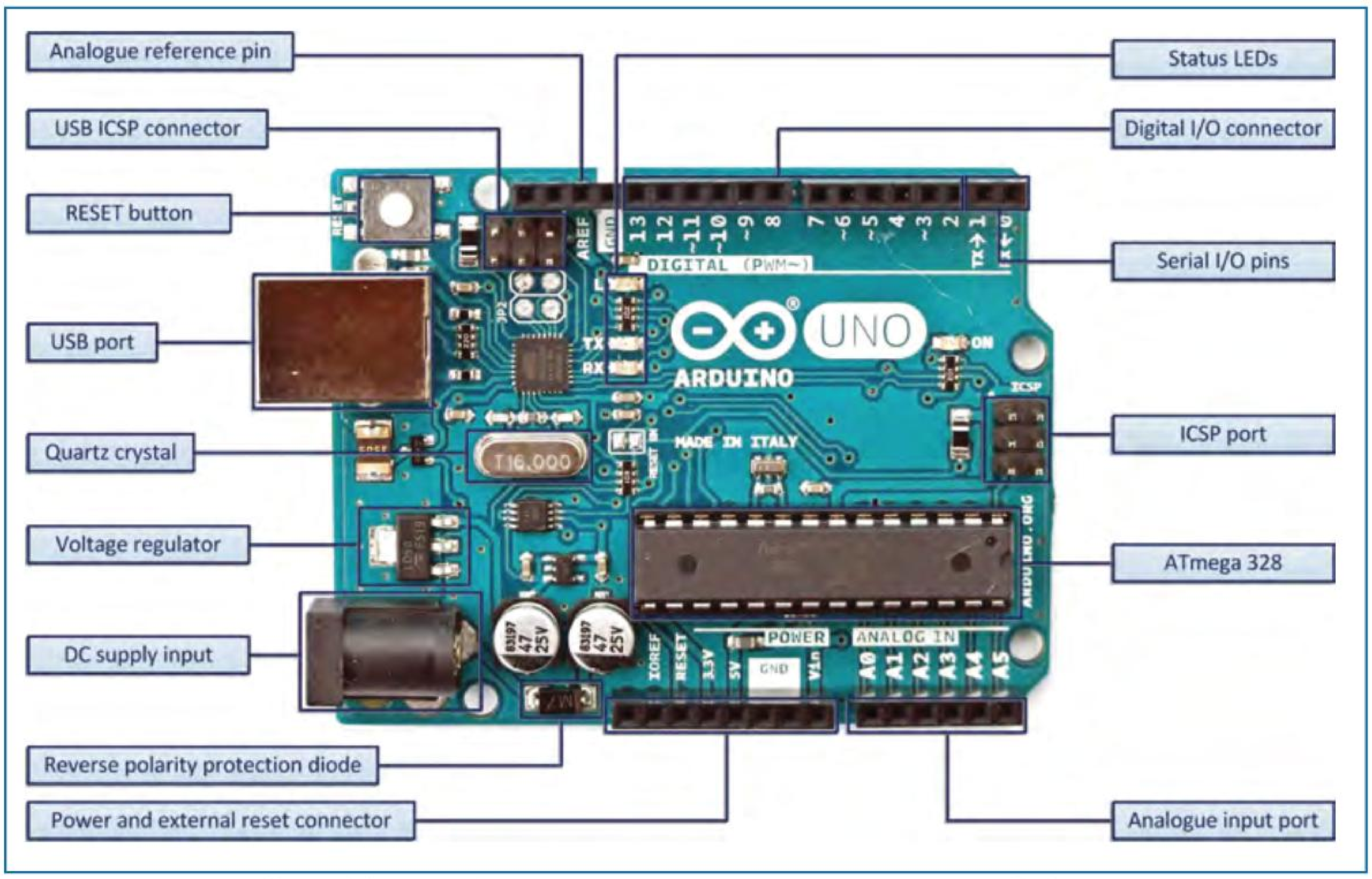


Fig.1.2. Uno board layout showing main components, power and I/O connectors

The Uno board measures approximately 69mm by 53mm and provides a total of 14 digital input/output lines, together with six analogue inputs. To compensate for the lack of conventional direct analogue *output* lines, signals on six of the 14 digital I/O lines can, where necessary, make use of pulse-width modulation (PWM) to generate up to six analogue outputs. Later in the series we will explain how this works, but for now you only need to be aware that, with appropriate circuitry, the Uno can produce analogue outputs as well as make use of regular analogue inputs. Fig.1.2 shows the Uno's board layout with the main components and connectors identified. The Arduino Uno technical specifications are shown in Table 1.1.

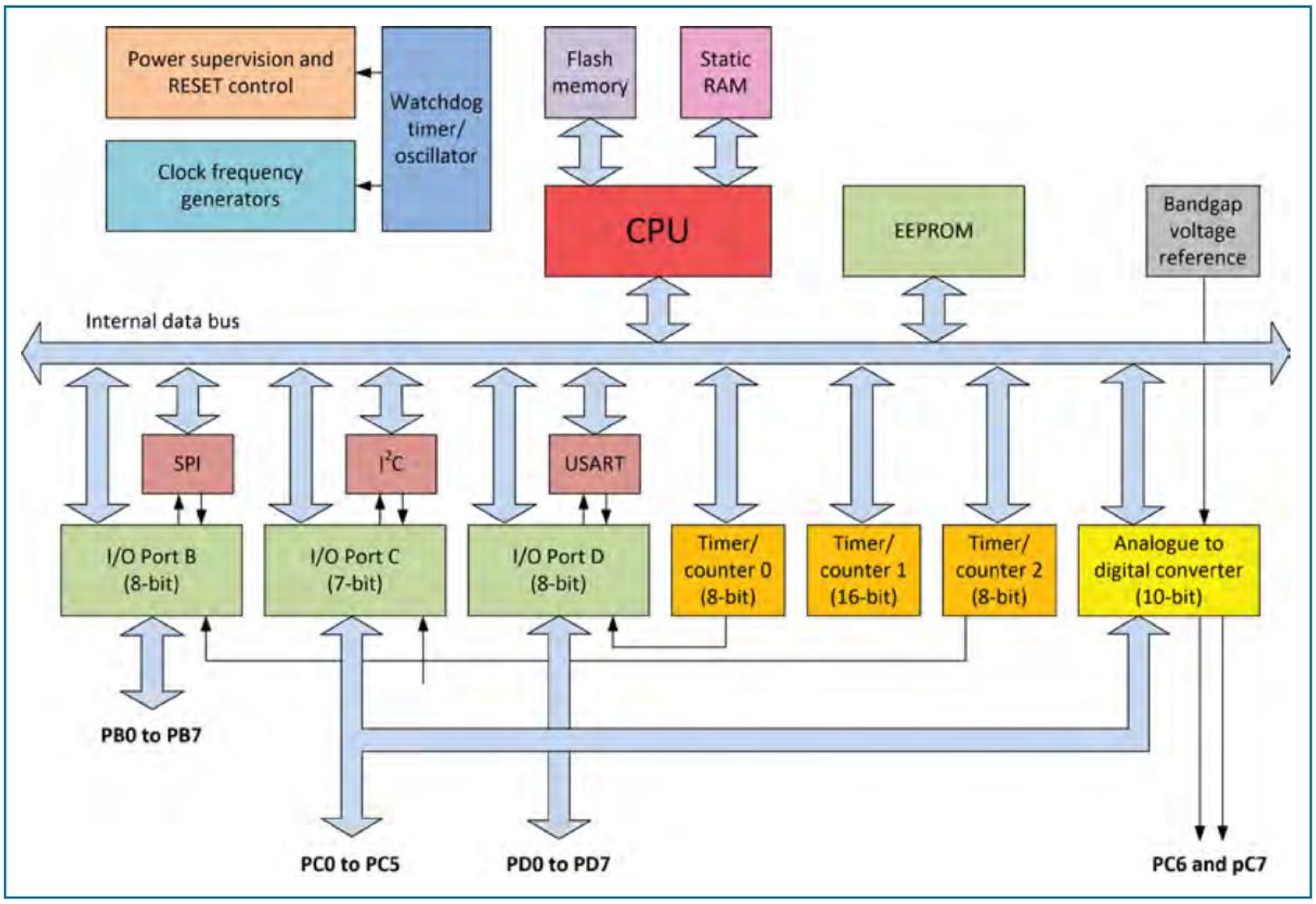

Power supervision and RESET control
Clock frequency generators
Watchdog timer/ oscillator
Flash memory
Static RAM
CPU
EEPROM
Bandgap voltage reference
Internal data bus
SPI
I²C
USART
I/O Port B (8-bit)
I/O Port C (7-bit)
I/O Port D (8-bit)
Timer/ counter 0 (8-bit)
Timer/ counter 1 (16-bit)
Timer/ counter 2 (8-bit)
Analogue to digital converter (10-bit)
PB0 to PB7
PC0 to PC5
PD0 to PD7
PC6 and pC7

Fig.1.3. Simplified internal schematic of the ATmega328

The ATmega328

The Uno is based on the popular ATmega328 processor, one of a family of high-performance, low-power 8-bit microcontrollers with 4, 8, 16 and 32Kbytes of in-system programmable memory. The ATmega328 offers the largest memory capacity of the series and it has 32Kbytes of flash memory used for storing program code (of which 512 bytes is reserved for bootloader code that will allow you to communicate with the device and upload your code to it). The ATmega328 also has 2Kbytes of static random access memory (SRAM) and 1Kbyte of electrically erasable programmable read-only memory (EEPROM).

The simplified internal arrangement of the ATmega328 is shown in Fig.1.3. The chip incorporates a variety of peripheral functions, including two 8-bit timer/counters with separate pre-scaler and compare mode and one 16-bit timer/counter with a separate pre-scaler. The chip incorporates six pulse-width modulated (PWM) channels which, with appropriate signal conditioning, can be used to provide analogue outputs. The device also incorporates a six-channel, 10-bit analogue-to-digital converter (ADC) and incorporates a variety of communications ports including a programmable serial USART, an SPI serial interface and a byte-oriented 2-wire serial I^2C compatible interface. For good measure, the chip also incorporates a programmable watchdog timer.

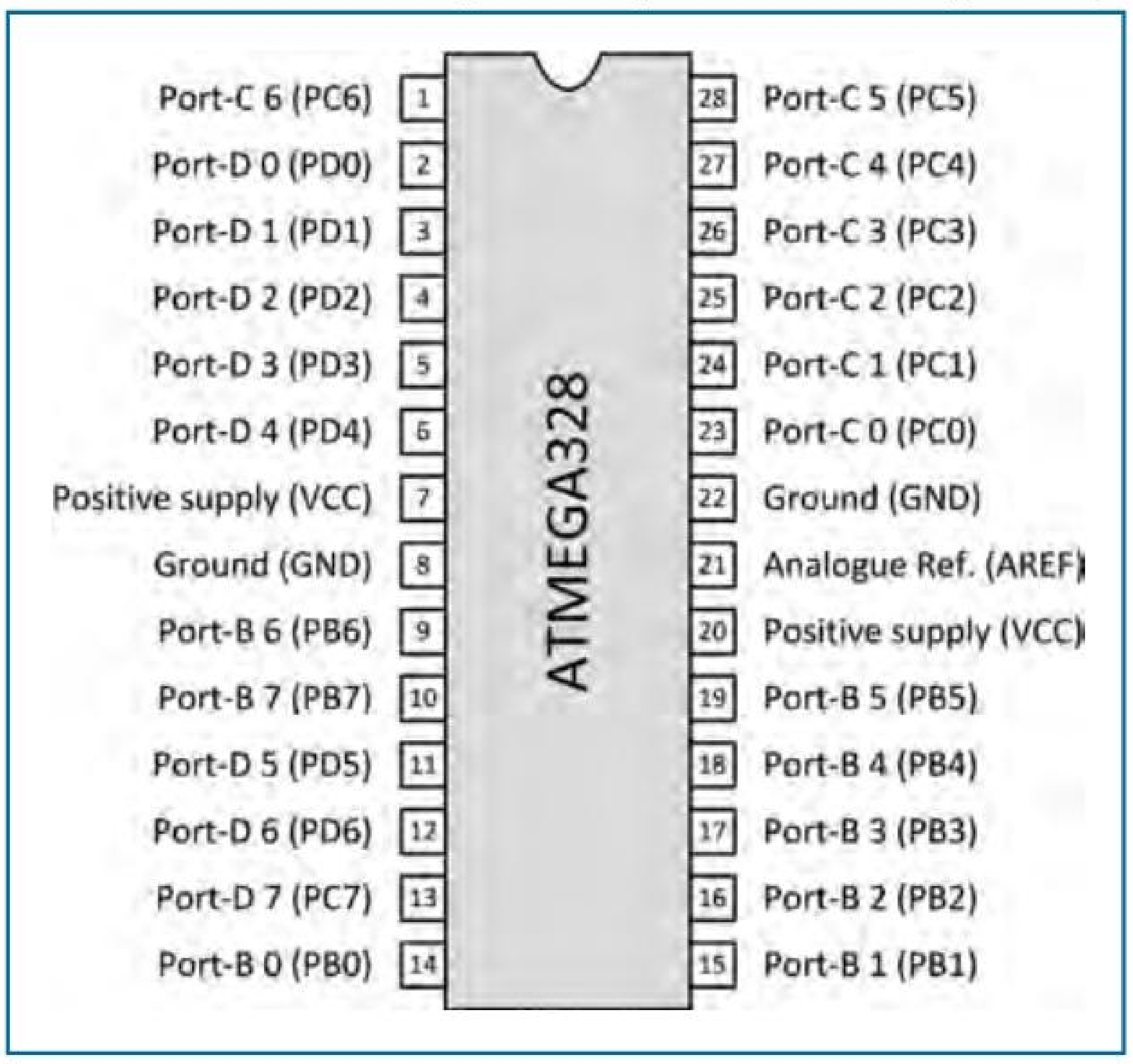

ATMEGA328
Port-C 6 (PC6) 1
Port-D 0 (PD0) 2
Port-D 1 (PD1) 3
Port-D 2 (PD2) 4
Port-D 3 (PD3) 5
Port-D 4 (PD4) 6
Positive supply (VCC) 7
Ground (GND) 8
Port-B 6 (PB6) 9
Port-B 7 (PB7) 10
Port-D 5 (PD5) 11
Port-D 6 (PD6) 12
Port-D 7 (PC7) 13
Port-B 0 (PB0) 14
28 Port-C 5 (PC5)
27 Port-C 4 (PC4)
26 Port-C 3 (PC3)
25 Port-C 2 (PC2)
24 Port-C 1 (PC1)
23 Port-C 0 (PC0)
22 Ground (GND)
21 Analogue Ref. (AREF)
20 Positive supply (VCC)
19 Port-B 5 (PB5)
18 Port-B 4 (PB4)
17 Port-B 3 (PB3)
16 Port-B 2 (PB2)
15 Port-B 1 (PB1)

Fig.1.4. Pin connections for the 28-pin DIP-package ATmega328

Alternative packages

At this point, it's important to be aware that the original 'genuine' version of the Arduino is supplied with a 28-pin dual-in-line package (DIP) version of the ATmega328 processor, the pin connections for which are shown in Fig.1.4. Cheaper clones and compatible versions are often supplied with differently packaged processors, usually 28-pin TQFP or MLF types. These processors are soldered directly to the printed circuit board and cannot ordinarily be removed, whereas the DIP version is mounted in a socket and can, if necessary, be removed and replaced. This alone is a good reason to do all your development work on a genuine Arduino board! For comparison, Fig.1.5. shows the different processors fitted to two versions of the Uno, genuine and clone respectively.

I/O lines and port configuration

The ATmega328 has a total of 23 input/output (I/O) lines. Before we expand on what these can do it is important to be aware that ATmega328 I/O lines can be software configured for different functions. As an example, pin 17 of the DIL package version of the ATmega328 is labelled 'PB3' (Port B, Bit 3). The pin provides master data output and slave data input when the chip is configured for use with the serial peripheral interface (SPI) bus. Alternatively, it can be configured to provide an external output for the PWM timer function or as a pin-change external interrupt source. We will explain how this works in a future instalment but, for the time being, it is just necessary to remember that the I/O pins can have

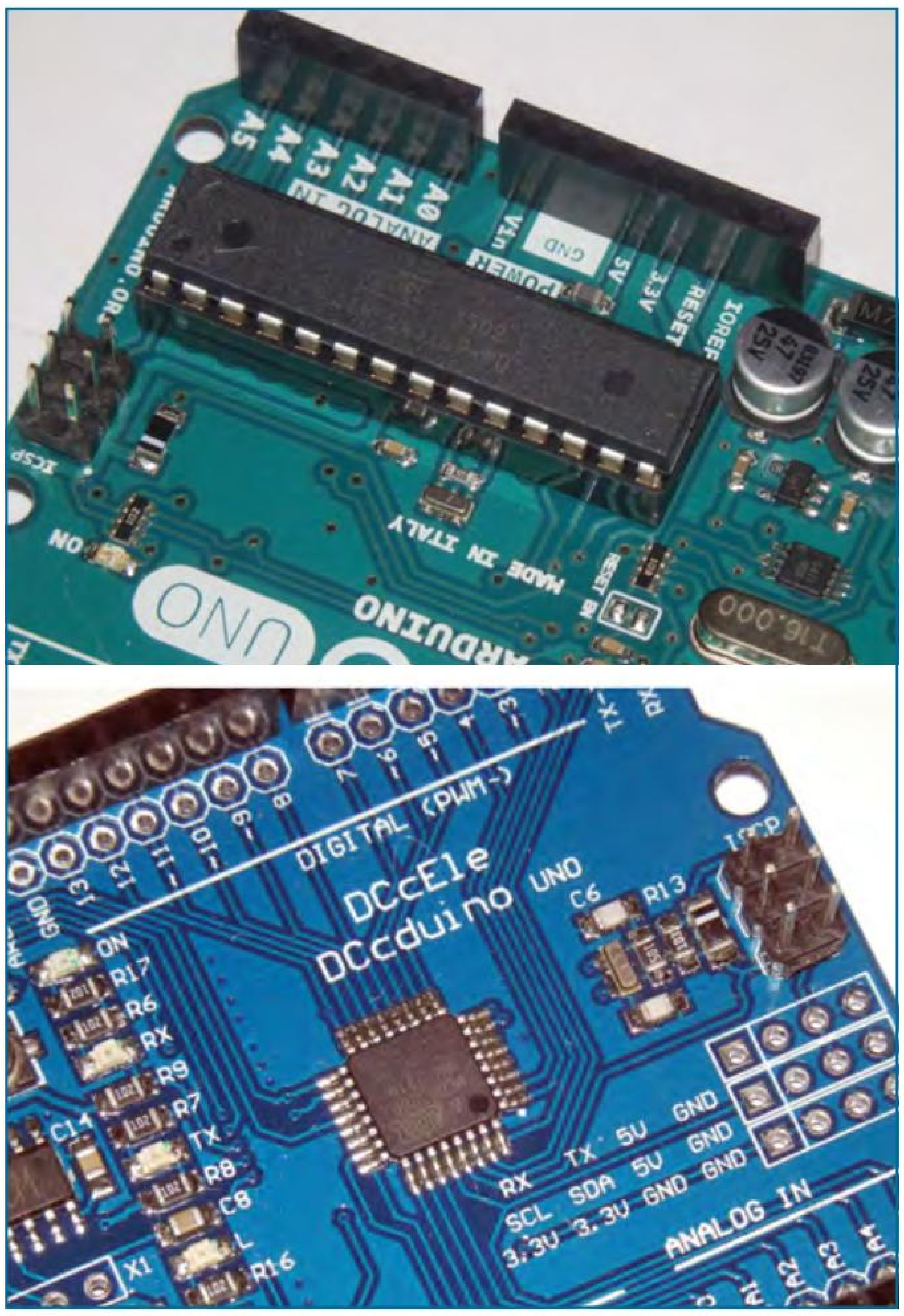


Fig.1.5. (top) 28-pin DIP and (bottom) 28-pin MLF package versions of the ATmega328 fitted to original and clone versions of the Uno

several different functions depending on the chip's software configuration.

Port-B (PB0 to PB7)

Port-B is an 8-bit bi-directional I/O port with internal pull-up resistors (which can be individually selected for each bit). The Port-B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port-B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port-B pins are placed in a tri-state (high-impedance) condition when a reset condition becomes active, even if the clock is not running. Depending on the clock selection fuse settings, PB6 can be used as input to the inverting oscillator amplifier and input to the internal clock operating circuit. In the same manner, PB7 can be used as output from the inverting oscillator amplifier. If the internal calibrated RC oscillator is used as chip clock source, PB6 and PB7 (pins 9 and 10 of the DIL package version of the ATmega328) are used as inputs the asynchronous Timer/Counter 2.

Port-C (PC0 to PC5)

Port-C is a 7-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The PC0 to PC5 output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port-C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port-C pins are tri-stated when a reset condition becomes active, even if the clock is not running. PC6 (pin-1 of the DIL packaged version of the ATmega328) can be fuse programmed for use as an I/O pin or to function as a RESET pin. In the latter case, a RESET will be generated when a low level is present on this pin.

Port-D (PD0 to PD7)

Port-D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port-D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port-D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port-D pins are tri-stated when a reset condition becomes active, even if the clock is not running.

USB interface

The Arduino's Universal Serial Bus (USB) interface is external to the ATmega328. In current versions of the Uno the interface is implemented using an ATmega8U2 CMOS RISC-based 8-bit microcontroller. This replaces the popular FTDI FT232 serial interface chip found in earlier versions and in many other microcontroller designs. The Uno's USB interface is brought out to a standard four-pin Type-A printed circuit board connector (see Fig.1.2).

The ATmega328 is programmed from the USB port using its own resident bootloader code that will let you upload your own code to it without the use of an external hardware programmer. Alternatively, you can bypass the bootloader so that you can then program the microcontroller through the Uno's in-circuit serial programming (ICSP) header.

Power supplies

The Uno can derive its power from various sources, including a powered USB port using the standard A-to-B USB cable that we mentioned earlier (see Fig.1.6). Alternatively, an external supply derived from a battery or AC-to-DC adapter can be connected to the external 2.1mm (centre-positive) DC connector. The power source is selected automatically. As a further alternative, a supply derived from a battery may be connected directly to the ground (GND) and input voltage (Vin) pins of the POWER header connector.

The specifications (see Table 1.1) state that operation should be from an external DC supply of between 6V and 20V. However, to ensure reliable operation we would recommend that the range of supply voltages is kept between 7V (minimum) and 12V (maximum). This makes a small 9V battery-derived supply ideal for applications where a mains supply is unavailable.

During software development it can be more convenient to supply power using the Uno's USB connector and a hub or other powered external USB device. In this case, the supply voltage will be +5V. The USB connector can also be used just to provide power for the Uno. In most cases this will involve the use of a USB charger and matching cable.

To provide power for external boards and 'shields', a separate 3.3V power rail is available from the Uno's on-board voltage regulator. It's important to note that the current available from this supply should not exceed 50mA. Having briefly described the Uno's hardware configuration it's now time to move on to explain how the digital and analogue I/O lines are configured and used for different applications.

Using digital I/O

Each of the 14 digital pins on the Uno can be configured as an input or output by using the appropriate C functions, `pinMode()`, `digitalWrite()`, and `digitalRead()`. All of the digital I/O lines operate at standard TTL-compatible levels. Each of the I/O pins can source or sink a maximum current of 40mA and internal pull-up resistors of around 20 to 50kΩ can be selected where necessary. Note that the internal pull-up facility is disabled by default). It is important to be aware that many of the digital I/O lines also have specialised functions (as previously mentioned).

Serial I/O using digital I/O pins 0 and 1

These include the serial RX and TX pins that can be used to receive (RX) and transmit (TX) TTL serial data using pins 0 and 1 respectively. These pins are connected to the corresponding pins of the ATmega8U2 serial USB-to-TTL device.

Fig.1.6. USB Type-A-to-Type-B connector

Interrupt inputs using digital I/O pins 2 and 3

These two pins are available for use with external interrupts. They can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. The `attachInterrupt()` function can be used to configure the interrupt feature.

Pulse-width modulation (PWM) output using digital I/O pins 3, 5, 6, 9, 10, and 11

These six lines can be used to provide outputs that are pulse-width modulated (PWM). This feature can be used to provide quasi-analogue outputs using the `analogWrite()` function.

Serial SPI communication using digital I/O pins 10, 11, 12 and 13

These four pins support SPI serial communication by providing SS, MOSI, MISO and SCK signals respectively. Note that although the underlying hardware supports this interface, SPI communication is not currently included in the Arduino language.

LED indication using digital I/O pin 13

An LED status indicator is provided for this (and only this) I/O pin. When the pin is high, the LED will be on, and when low, the LED will be off. The built-in LED provides a handy way of testing simple I/O code routines without the need to connect an external indicator.

Using analogue I/O

In addition to the 14 digital I/O lines, the Uno has six analogue inputs, each of which provide 10 bits of resolution (1024 different values). By default, they measure from ground to 5V, though it is possible to change the upper end of the measurement range using the AREF pin and the `analogReference()` function (more of this in a future instalment). As with the digital I/O lines, some of the analogue input pins also have specialised functions.

I^{2}C communication using analogue pins 27 and 28

Analogue I/O port lines 4 and 5 (pins 27 and 28 respectively) can be used to provide access to the SDA and SCL signals respectively used to facilitate the two-wire interface (TWI or I^{2}C).

Analogue output (as distinct from input) can be obtained from six of the digital I/O lines (pins 5, 11, 12, 15, 16 and 17). In a future instalment we will explain how this works, but for now, you just need to know that by switching the digital outputs on and off and averaging the voltage produced it is possible to produce an analogue voltage. For example, if one of the digital outputs is alternately taken high (+5V) for 50% of the time and low (0V) for 50% of the time then the average voltage produced will be +2.5V.

Communicating with the Uno

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega8U2 (see earlier) provides serial communication over USB and appears as a virtual COM port when used with software running on an external Windows or Linux-based computer. The ATmega8U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, when using some versions of Windows, clones and compatibles, a driver information (.INF) file maybe required (see later).

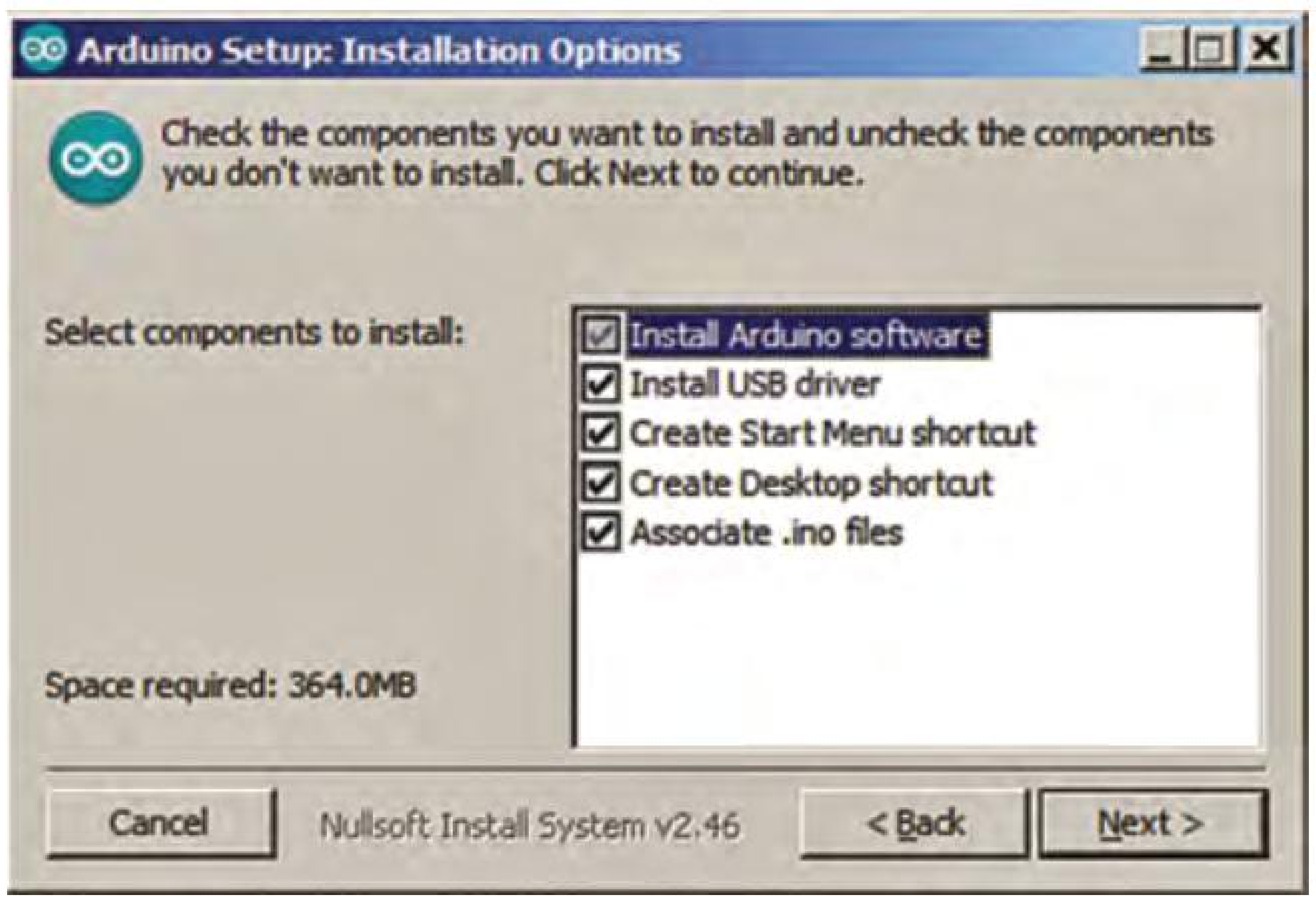
The Arduino's integrated development environment (IDE) incorporates a serial monitor which allows simple text data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for TTL serial communication using pins 0 and 1). A software serial library allows for serial communication on any of the Uno's digital pins. As already noted, the Uno can also support I^{2}C (TWI) and SPI communication. This is ideal for communication with external hardware devices, sensors and transducers.

The Arduino Uno has a resettable polysilicon fuse that's designed to protect against short-circuit and overcurrent conditions. If more than 500mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed. Although computers usually have their own internal protection, this fuse does provide you with an extra layer of protection.

Arduino Workshop: Installing and configuring the IDE

Before you can begin to enter code into your Arduino you will need to connect it to a PC that has a copy of the Arduino's IDE installed on it. The process is quite painless, but does require a machine with an Internet connection so that you can download the latest version of the IDE package.

We've installed the IDE package successfully on a whole host of different computers, including some running 32- and 64-bit versions of Windows 7, 8 and 10 and also a couple running different flavours of Linux. The step-by-step procedure described here was carried out on a computer running Windows 7, but the process is similar, if not quite identical, on other machines. Note that an installation under Linux may require the installation of the Java run-time environment (JRE) if not already installed. Also, if you are using a low-cost Arduino clone (ie, not a 'genuine' Arduino) you might need a different USB driver from the one supplied with the official IDE package.


Arduino Setup: Installation Options

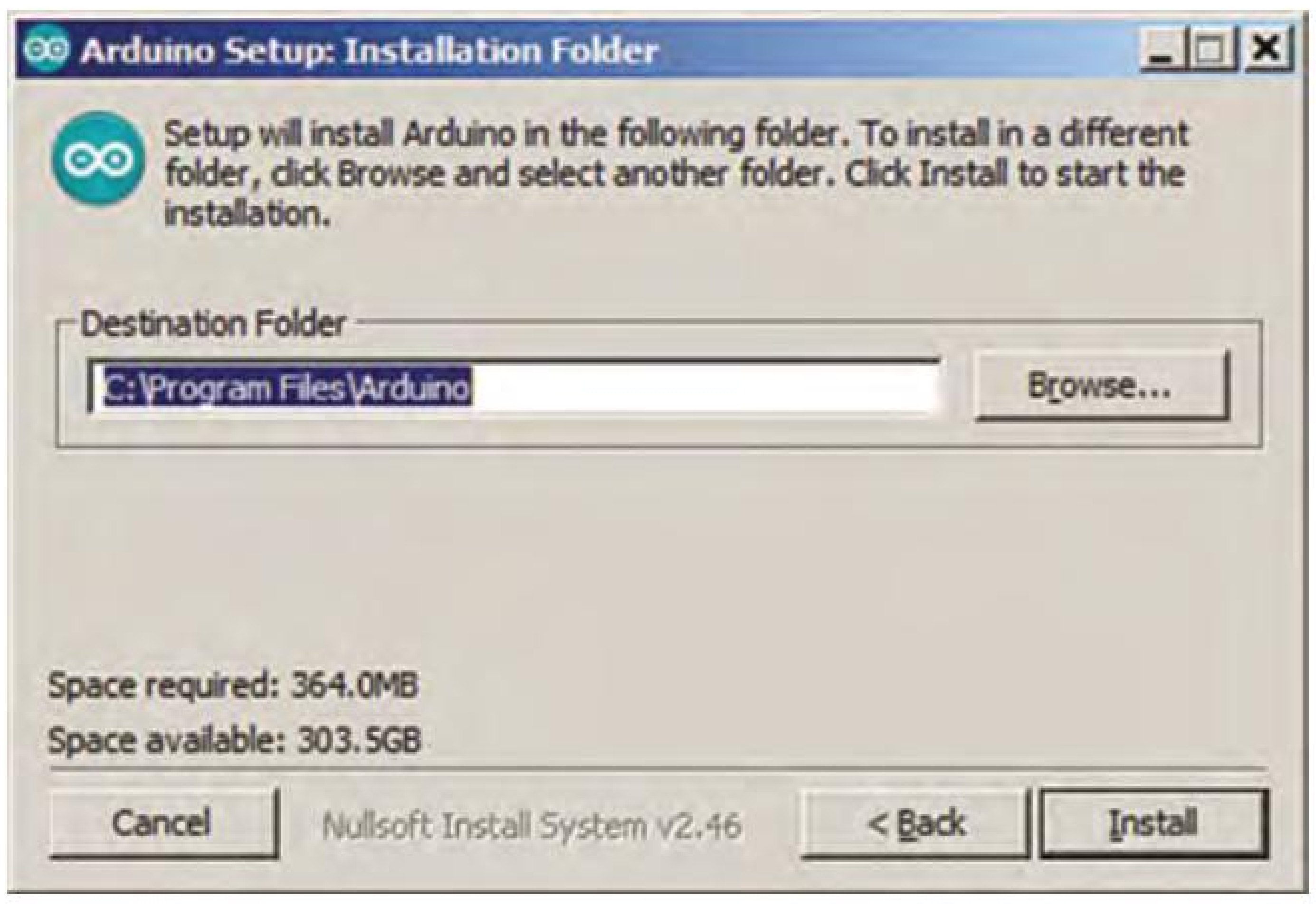
Check the components you want to install and uncheck the components you don't want to install. Click Next to continue.

Select components to install:

☑ Install Arduino software
☑ Install USB driver
☑ Create Start Menu shortcut
☑ Create Desktop shortcut
☑ Associate .ino files

Space required: 364.0MB

Fig.1.7. Selecting installation options


Arduino Setup: Installation Folder

Setup will install Arduino in the following folder. To install in a different folder, click Browse and select another folder. Click Install to start the installation.

Destination Folder

C:\Program Files\Arduino

Space required: 364.0MB
Space available: 303.5GB

Fig.1.8. Choosing a destination folder for the installation

1. Open your web browser and go to: **www.arduino.cc** (the official Arduino home page). When the page has loaded, click on 'Download' in the top menu bar and then select the IDE version for your machine.
2. At this point you will be asked if you would like to make a contribution to the development of the software. You can either click on 'Just download' or 'Contribute and download'. When you've made your choice, the installation file will be downloaded to your computer. The download is quite large, so depending on the speed of your Internet connection you may have to wait for a minute or two for the download to complete.
3. Next, click on the installer or unzip the file (depending on which version you have chosen) and follow the prompts. You can select installation options (see Fig.1.7) and choose a destination folder (see Fig.1.8). Finally, click on 'Install' to start the installation process.
4. Depending on the speed of your computer the installation process may take a few minutes, but as it nears completion you will be given the option of installing a USB driver (see Fig.1.9). This driver will allow your computer to communicate with a standard Arduino by means of the USB port. We recommend that you click on 'Install' to install this additional system software (not part of the IDE itself). Note that if you are using one or more different versions of the Arduino you may need to install specific drivers in order to cope with different versions. If you are not using a 'genuine' Arduino but are using a low-cost clone you may need to install an alternative USB driver. Information on how to do this is usually supplied with the microcontroller in question.
5. When the installation is complete and the USB driver has been added you can click on 'Close' to return to your normal desktop. Note that during IDE installation the progress can provide you with a detailed list of the files that are being installed on your system (see Fig.1.10).
6. If you have previously clicked on the option to create a shortcut (from either the desktop or for the start menu) you will be able to click on it and start the IDE for the first time. If all is well you should see a window like that shown in Fig.1.11.
7. Now connect your Arduino board to the PC using one of its (powered) USB ports. At this point, and since the USB supplies +5V there's no need for a separate DC supply for the microcontroller. The various LEDs on the Arduino should flash momentarily as the system boots and, if it is 'new out of the box' it is likely that the 'L' LED will be flashing on and off slowly. This confirms that power is being supplied by the host computer and that the Arduino is functioning properly.
8. Next, you will need to tell the IDE software what version of the Arduino you are using and which port is being used to communicate with it. Click on 'Tools' from the menu bar at the top of the window and then on 'Board' from the drop-down. Select your particular Arduino version from the list that appears (see Fig.1.12). Note that the default will be 'Genuine Arduino Uno'.

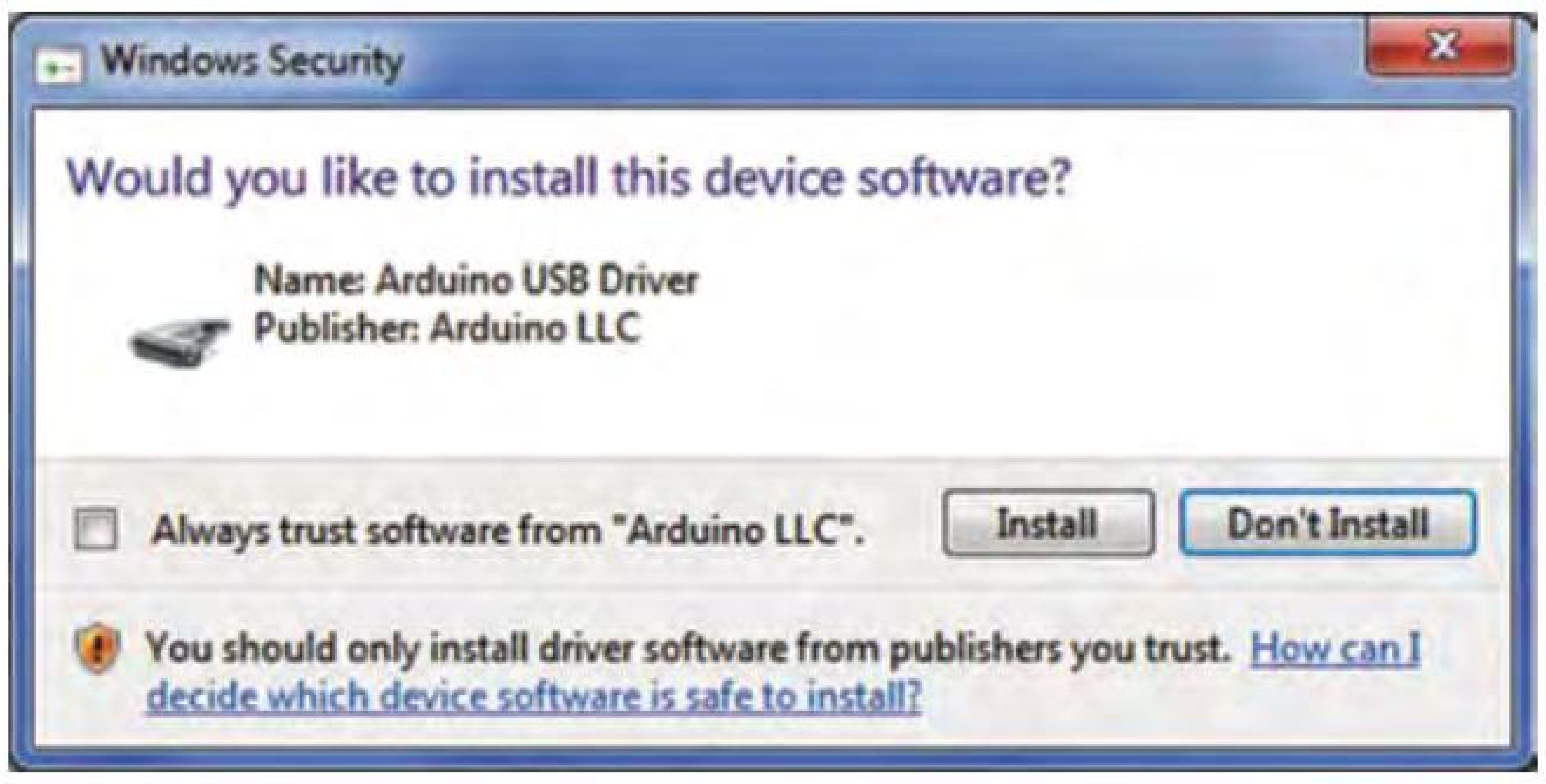
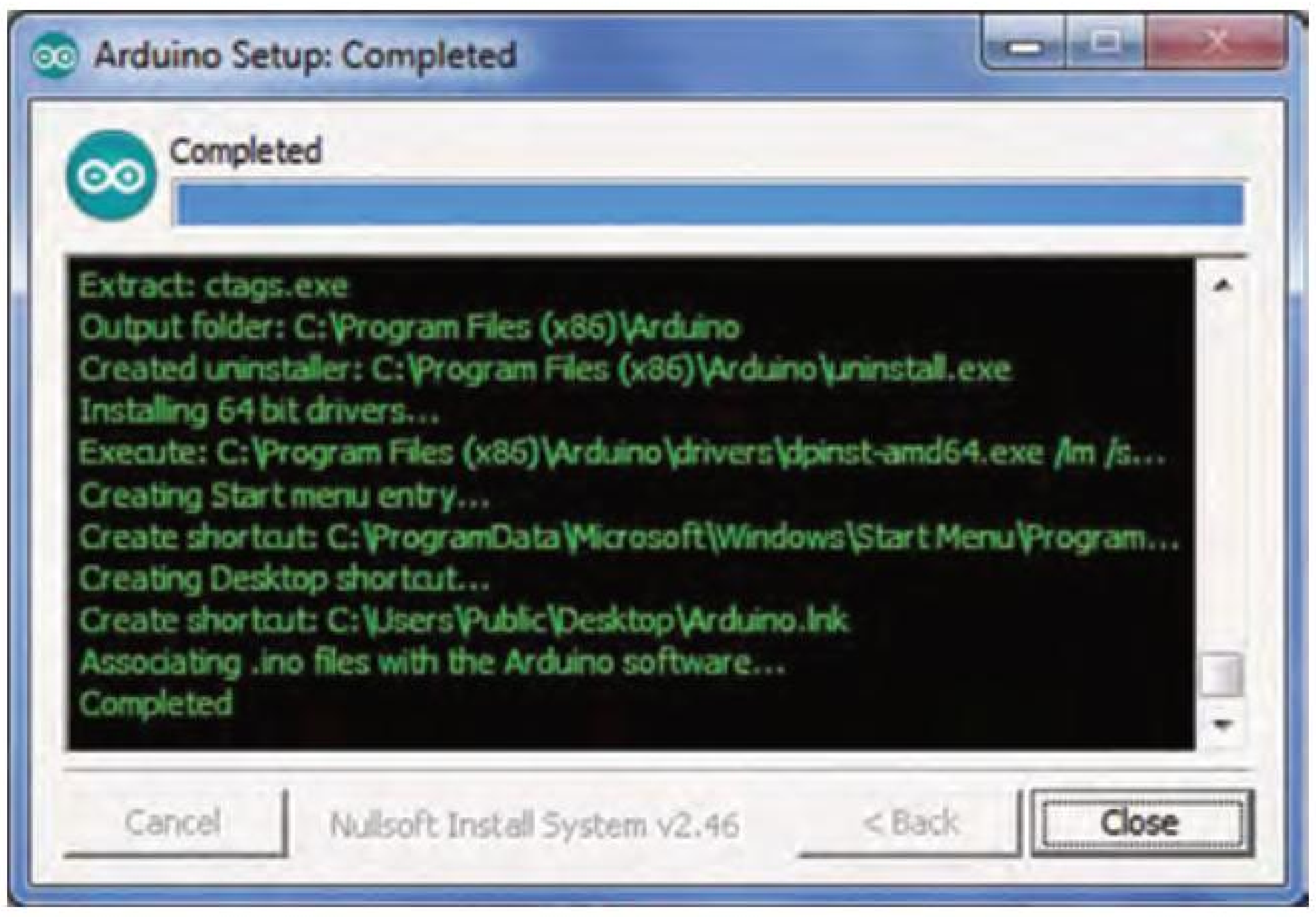

Windows Security
Would you like to install this device software?
Name: Arduino USB Driver
Publisher: Arduino LLC
☐ Always trust software from "Arduino LLC".
Install
Don't Install
You should only install driver software from publishers you trust. How can I decide which device software is safe to install?

Fig.1.9. Option to select a USB driver for use with the Arduino software


Arduino Setup: Completed
Completed
Cancel
Nullsoft Install System v2.46
< Back
Close

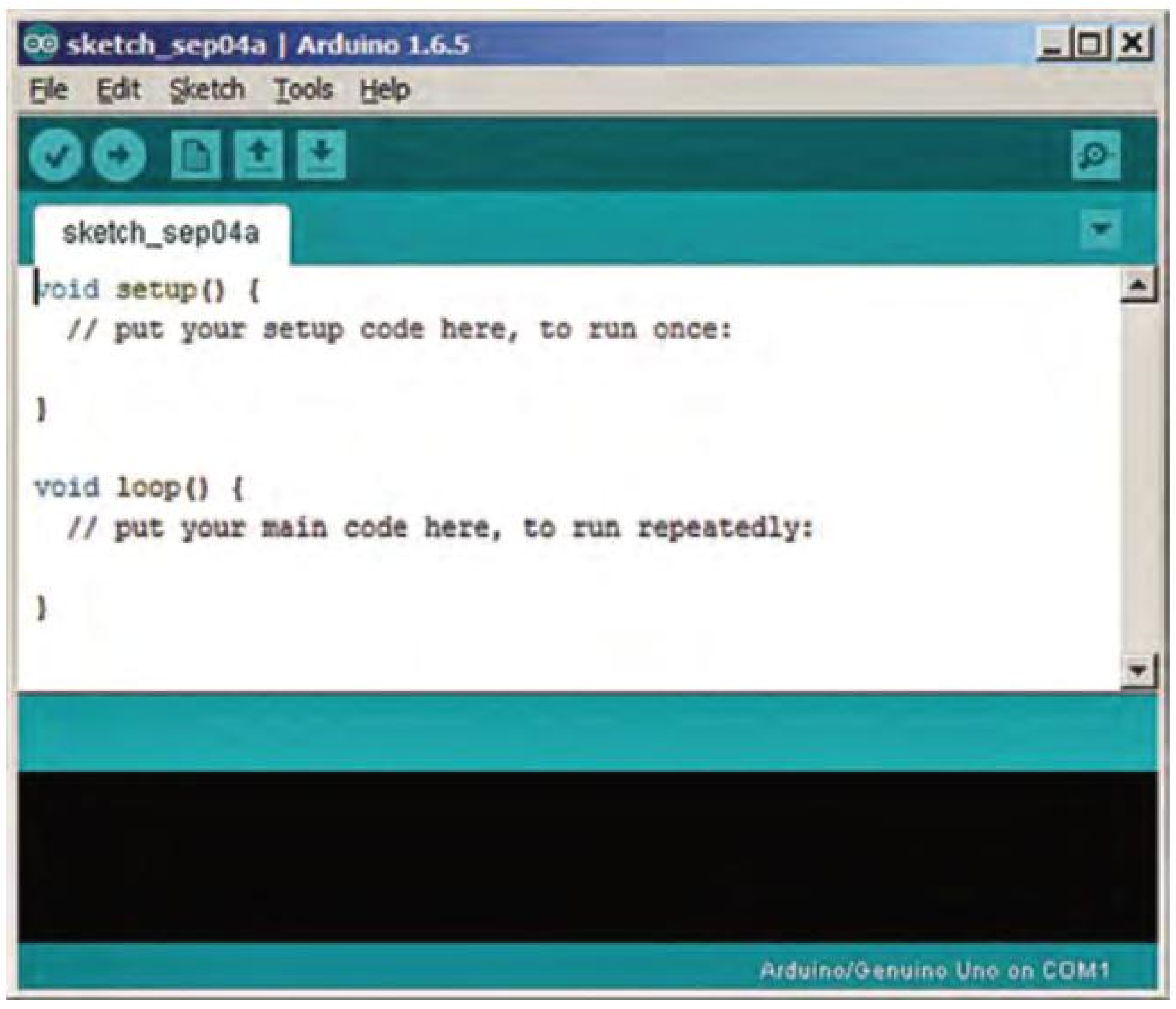
```
Extract: ctags.exe
Output folder: C:\Program Files (x86)\Arduino
Created uninstaller: C:\Program Files (x86)\Arduino\uninstall.exe
Installing 64 bit drivers...
Execute: C:\Program Files (x86)\Arduino\drivers\dpinst-amd64.exe /lm /s...
Creating Start menu entry...
Create shortcut: C:\ProgramData\Microsoft\Windows\Start Menu\Program...
Creating Desktop shortcut...
Create shortcut: C:\Users\Public\Desktop\Arduino.lnk
Associating .ino files with the Arduino software...
Completed
```

Fig.1.10. Detailed information is available during IDE installation

9. Now you will need to tell the IDE software to select 'Port' from the 'Tools' drop-down menu and click on the port that you are using. The default will be 'COM1' but we have selected 'COM7' in Fig.1.13.
10. If you now look at the bottom right of the IDE window you should see that the status message has changed, indicating the board type and port number that you are using. If everything is as you expect you can now test out your connection from the IDE to the Arduino.
11. Click on 'Sketch' from the menu bar and then 'Verify/compile'. This will compile the current empty sketch and, after a short time. You should notice the Arduino's LEDs flashing and a 'Done compiling' message should appear. You are now ready to get to grips with your first Arduino program. If that's the case then move on quickly to the section entitled – *Get Real: Your first Arduino sketch.*

If things don't work

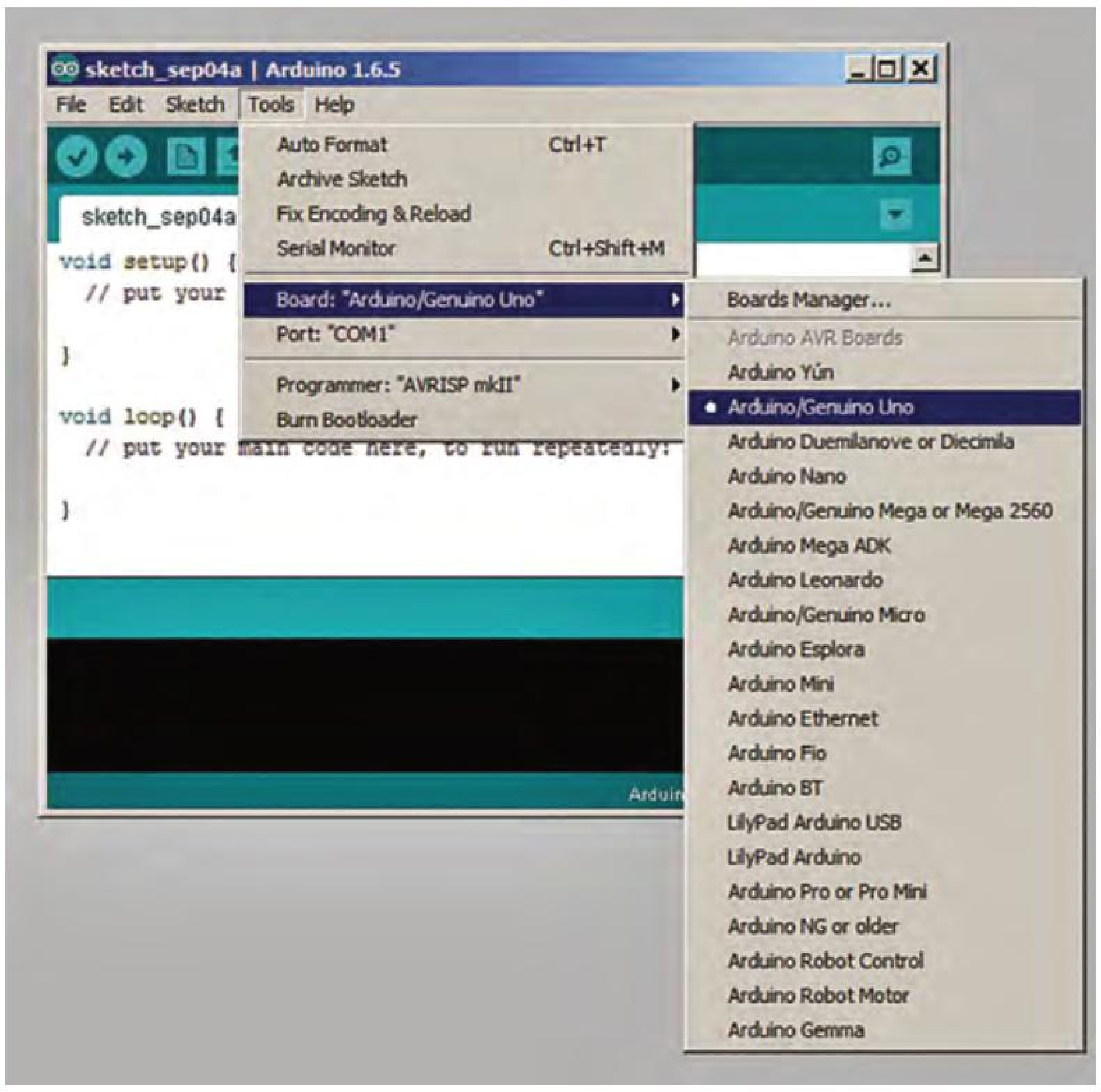
Sometimes you might find that your code upload doesn't work because the Arduino IDE fails to connect with your Uno. Getting your program code onto your Arduino involves several stages, and if any of them have problems, the upload can fail. Reasons for a failed upload can include driver problems as well as incorrect board and serial port selection. There can also problems with the physical connection to the port, a missing bootloader or the Uno's fuse settings.


sketch_sep04a | Arduino 1.6.5
File Edit Sketch Tools Help
sketch_sep04a

```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Arduino/Genuino Uno on COM1

Fig.1.11. The IDE

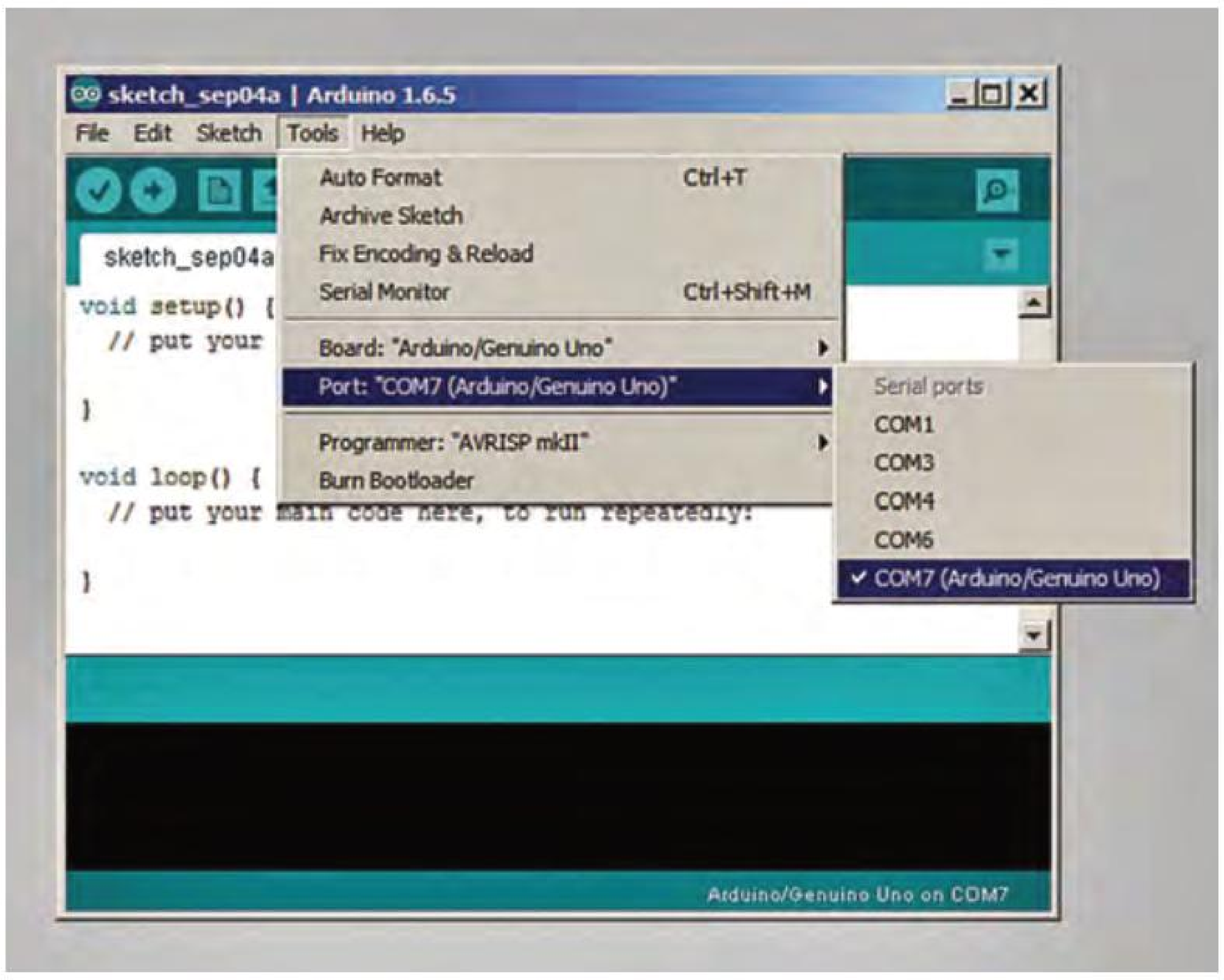

sketch_sep04a | Arduino 1.6.5
File Edit Sketch Tools Help
sketch_sep04a
Auto Format Ctrl+T
Archive Sketch
Fix Encoding & Reload
Serial Monitor Ctrl+Shift+M
Board: "Arduino/Genuino Uno"
Port: "COM1"
Programmer: "AVRISP mkII"
Burn Bootloader
Boards Manager...
Arduino AVR Boards
Arduino Yún
● Arduino/Genuino Uno
Arduino Duemilanove or Diecimila
Arduino Nano
Arduino/Genuino Mega or Mega 2560
Arduino Mega ADK
Arduino Leonardo
Arduino/Genuino Micro
Arduino Esplora
Arduino Mini
Arduino Ethernet
Arduino Fio
Arduino BT
LilyPad Arduino USB
LilyPad Arduino
Arduino Pro or Pro Mini
Arduino NG or older
Arduino Robot Control
Arduino Robot Motor
Arduino Gemma
Arduin

```
void setup() {
  // put your

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Fig.1.12. Selecting your Arduino version

The IDE displays error messages in a scrolling list at the bottom of the IDE window (see Fig.1.14). In this particular case the IDE is reporting that COM Port 7 is unavailable. By clicking on Tools and then Port from the drop-down menu the current configuration is displayed. This shows the Arduino Uno using COM Port 9.

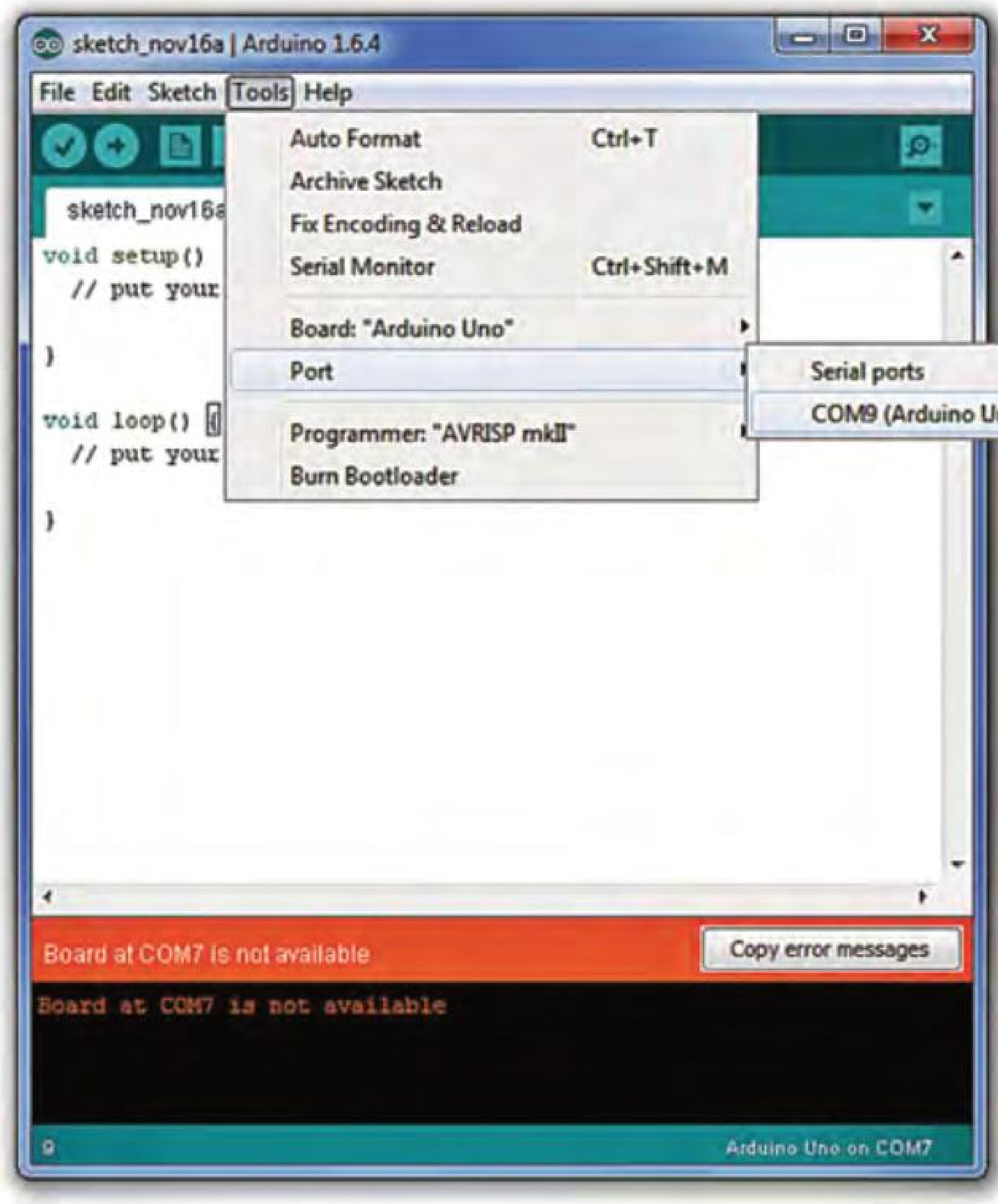
If your port doesn't appear, try restarting the IDE with the board connected to the computer. On the Mac, the serial port should be something like: `/dev/tty.usbmodem621` for the Uno or `/dev/tty.usbserial-A02f8e` for older, FTDI-based boards. On Linux, it should be `/dev/ttyACM0` or similar (for the Uno) or `/dev/ttyUSB0` or similar for older boards. On Windows, it will be a COM port but you'll need to check in the Device Manager (under Ports) to see which one. If you find that there's no serial port allocated to your Arduino board you will need to check that you have the correct driver installed. In the case of Arduino, the drivers work by providing a virtual serial port (or virtual COM port).


sketch_sep04a | Arduino 1.6.5
File Edit Sketch Tools Help
sketch_sep04a
Auto Format Ctrl+T
Archive Sketch
Fix Encoding & Reload
Serial Monitor Ctrl+Shift+M
Board: "Arduino/Genuino Uno"
Port: "COM7 (Arduino/Genuino Uno)"
Programmer: "AVRISP mkII"
Burn Bootloader
Serial ports
COM1
COM3
COM4
COM6
✓ COM7 (Arduino/Genuino Uno)

```
void setup() {
  // put your

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Arduino/Genuino Uno on COM7

Fig.1.13. Selecting the port to be used for communicating with your Arduino version


sketch_nov16a | Arduino 1.6.4
File
Edit
Sketch
Tools
Help
sketch_nov16a
Auto Format Ctrl+T
Archive Sketch
Fix Encoding & Reload
Serial Monitor Ctrl+Shift+M
Board: "Arduino Uno"
Port
Programmer: "AVRISP mkII"
Burn Bootloader
Serial ports
COM9 (Arduino Uno)
Copy error messages

```
void setup()
  // put your

}

void loop() {
  // put your

}
```

```
Board at COM7 is not available
```

```
Board at COM7 is not available
```

```
9                                   Arduino Uno on COM7
```

Fig.1.14. Error message resulting from incorrect port setting

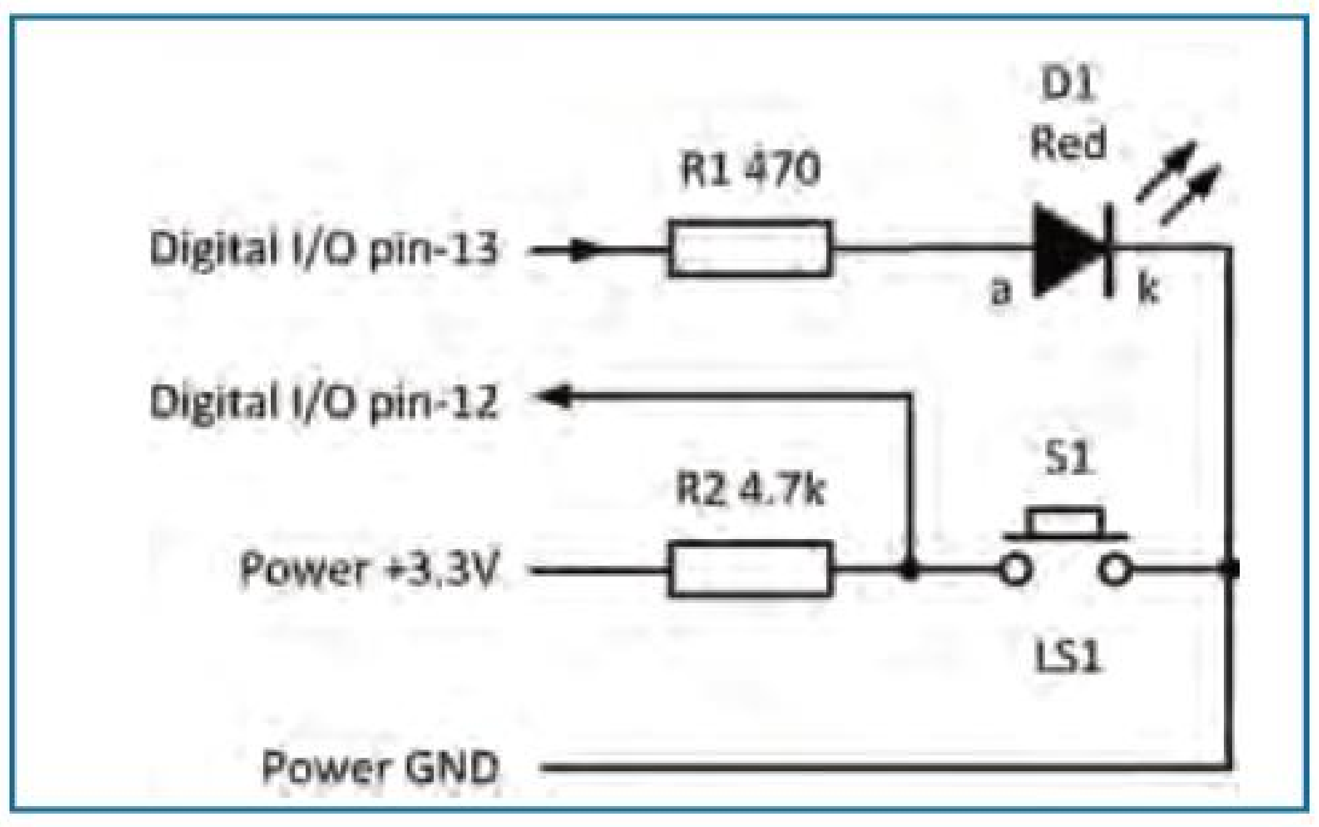

D1
Red
R1 470
Digital I/O pin-13
a
k
Digital I/O pin-12
R2 4.7k
S1
Power +3.3V
LS1
Power GND

Fig.1.15. Circuit of the LED and switch interface

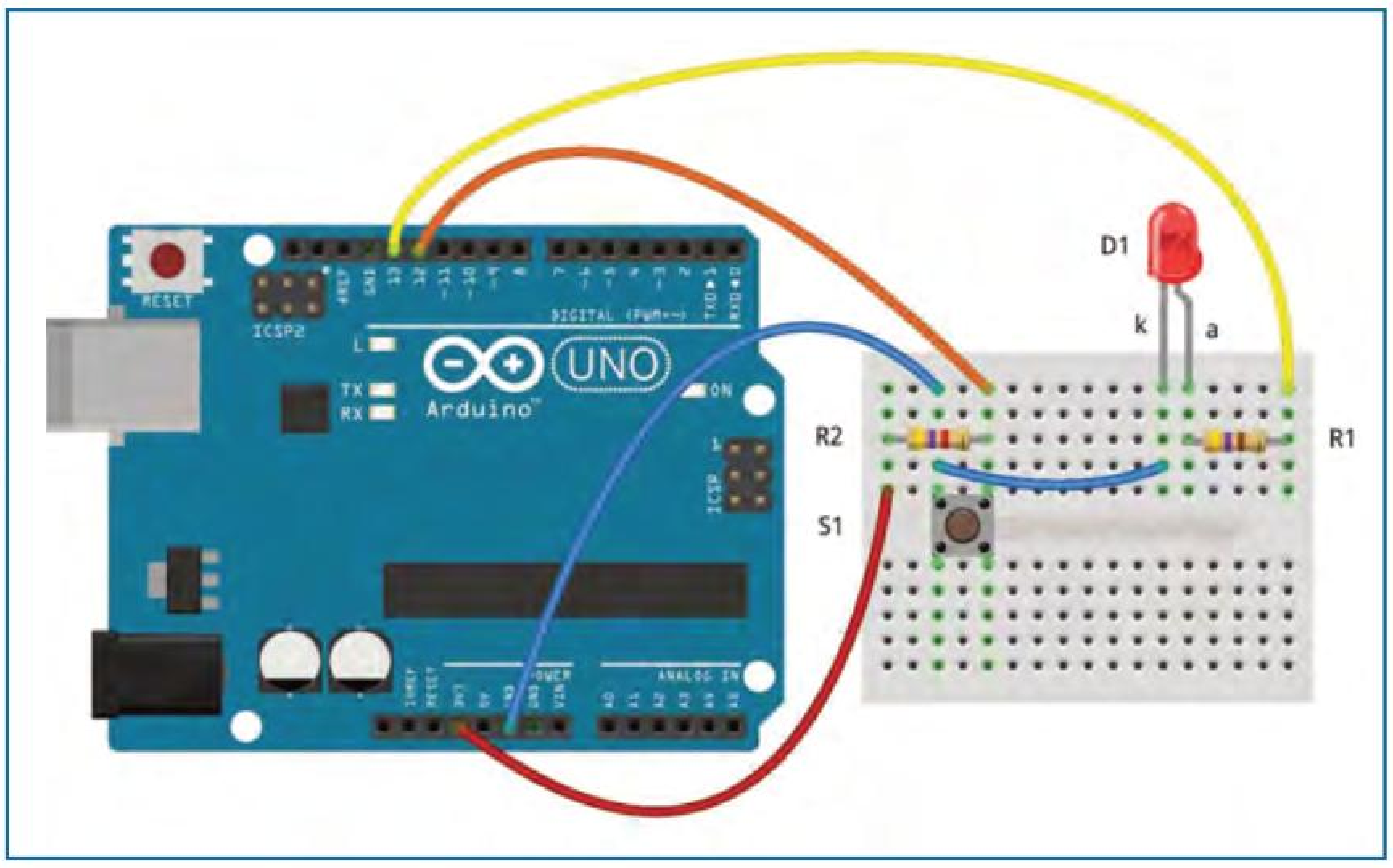

D1
k
a
R2
R1
S1

Fig.1.16. Fritzing breadboard arrangement for Fig.1.15

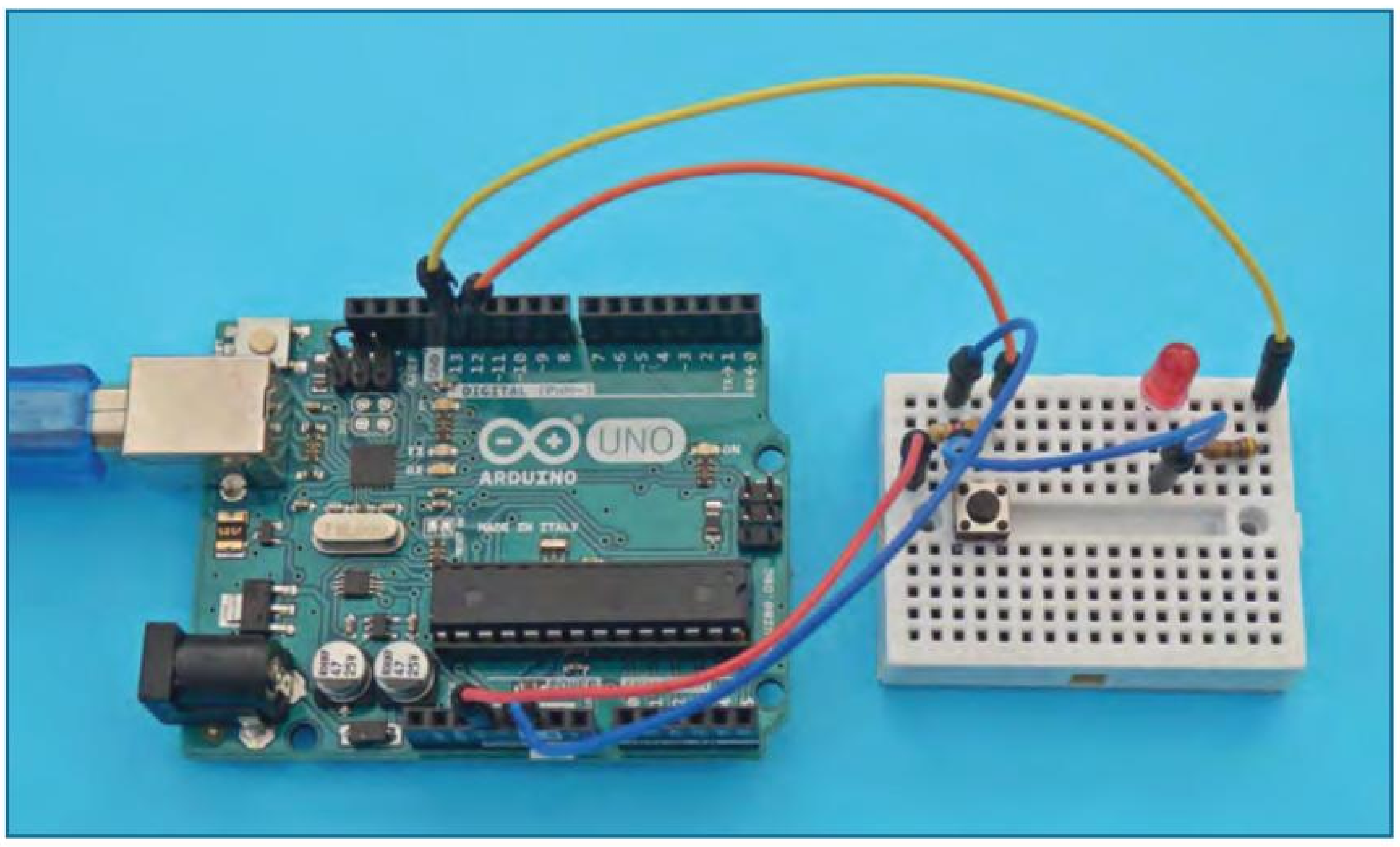


Fig.1.17. Actual breadboard arrangement

The Arduino Uno uses the standard USB CDC drivers that are normally provided by the operating system. These drivers allow the host computer to communicate with the ATmega8U2 on the Arduino board. Some other Arduino boards use FTDI drivers to communicate with an FTDI chip on the board (or in the USB-serial convertor).

The easiest way to check if the drivers for your board are installed correctly is by clicking on Tools and then Port from the drop-down menu (see Fig.1.14). On Windows 7 (particularly the 64-bit version), you might need to go into the Device Manager and update the drivers for the Uno. Just right click on the device (the board should be connected to your computer), and point Windows at the appropriate driver information (.INF) file. You will find this located in the Drivers directory of the Arduino software (not in the FTDI USB Drivers sub-directory). Further information concerning a failed driver installation is available from the official Arduino website.

Finally, it's important to remember that you will be unable to communicate with the Arduino if there's no bootloader present. It's easy to check this by simply resetting the board (by removing the power or pressing the reset button) and noting the state of the L-LED (connected to digital I/O pin-13). If the bootloader is present this LED should start to blink. If the LED doesn't blink, it's likely that the bootloader is missing. We will explain how a missing bootloader can be reinstated in a future instalment of *Teach-In 2016*.

Get Real : Your first Arduino sketch

In our first *Get Real* it's time for you to explore some of your new Arduino's capabilities and try out your first Arduino program, or 'sketch'. To keep things simple we've minimised the need for anything much in the way of additional hardware, so you will only need a mini-breadboard and a few commonly available components. The aim of this exercise is simply to control an LED from a switch, but if you are already familiar with this task feel free to jump forward to *Coding Quickstart* or *Arduino World*.

You will need

Arduino Uno with power supply
USB A-to-B cable
Computer with an available powered USB port
Mini-breadboard with a selection of coloured connecting leads
1 standard red LED
2 470Ω resistors (R1 and R3)
1 4.7kΩ resistor (R2)
Miniature push-button switch
Miniature loudspeaker of between 8Ω and 40Ω impedance

Circuit

The circuit of our LED and switch interface is shown in Fig.1.15. The LED (D1) is connected to the Arduino's Digital I/O pin-13, which will be configured as an output. The push-button switch (S1) will be connected to Digital I/O pin-12 configured as an input. R1 is connected in series with D1 to limit the LED current, while R2 is used to pull-up the input voltage to a HIGH (+3.3V) level when S1 is not being operated.

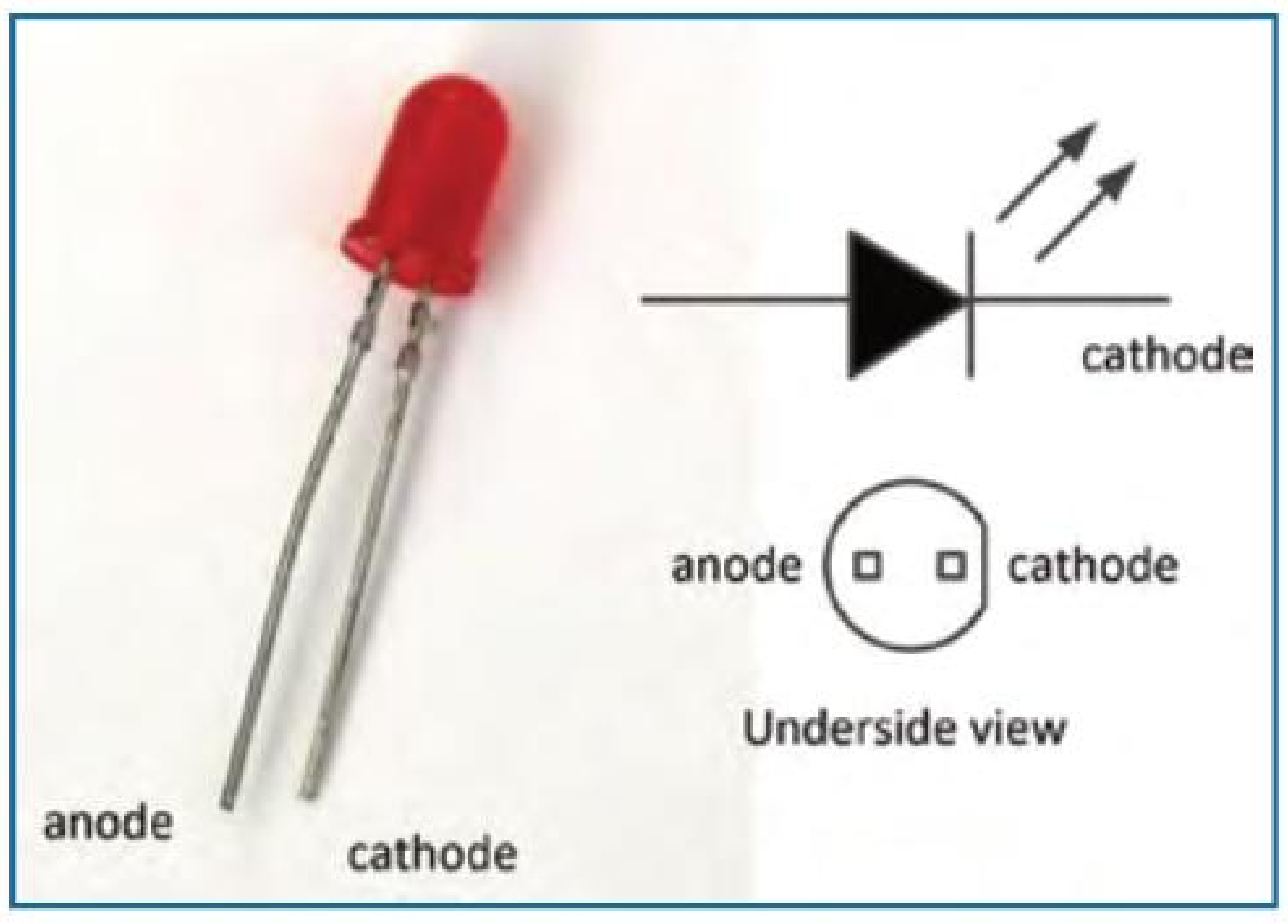

cathode
anode
cathode
Underside view
anode
cathode

Fig.1.18. LED connections

Breadboard layout

The components are shown mounted on the mini-breadboard in Fig.1.16. The LED will need to be connected with the correct polarity so that its cathode (the shorter of the two leads) is connected to 0V, as shown in Fig.1.18.

Code

Listing 1 shows the code sketch for the LED and switch application (you might not understand what all of the code does, but things will become clearer as we progress through the series):

The code must be entered into the IDE and then saved before compiling and uploading it to the Arduino as described earlier in *Arduino Workshop*. Note how we've added comments to the code in order to explain what's going on. Notice also how we've indented the lines and added spacing in order to make the code more readable. In a future *Teach-In 2016* we will explain this in more detail.

Listing 1

```
/* Simple LED and button example. Uses an external button
connected to pin-12 to control an LED connected to pin-13
*/

int inButton = 12;  // Switch connected to digital pin-12
int outLED = 13;    // LED connected to digital pin-13

boolean LEDstate = LOW;

void setup() {
  pinMode(inButton, INPUT);  // Button is an input
  pinMode(outLED, OUTPUT);   // LED is an output
}

void loop() {
  if (digitalRead(inButton) == LOW)
  // button has been pressed so turn the LED 'on'
  {
  LEDstate = HIGH;
  digitalWrite(outLED, LEDstate);
  }
  else
  // button has been released so turn the LED 'off'
  {
  LEDstate = LOW;
  digitalWrite(outLED, LEDstate);
  }
}
```

Before you start to enter your code click on File and New to produce a new editing window with a blank code template. You will find that the IDE has already started you off by adding empty `setup()` and `loop()` functions. You can now type in your code as shown above. When you finish, don't forget to save your work by clicking on 'File' and 'Save' or 'Save As...'. Next, click on 'Sketch' and 'Verify/Compile'. When you've corrected any coding errors that the compiler reports you will be ready to upload your code to the Uno. Just click on the upload arrow and watch the progress report. The LEDs on the Uno should flash and the code should begin to execute. At this point, D1 should become illuminated (along with the L-LED on the Uno board) whenever the push-button is pressed.

Toggle action

In many cases it might be desirable to 'toggle' the state of an output line rather than simply turn it on when the push-button is pressed and off when it is released. With the toggle action the LED will become illuminated when the button is first pressed and it will remain illuminated until the button is pressed again (after which it will remain turned turn off). In other words, every time the button is pressed the state of the LED will change. In order to accomplish the toggle action the Uno will need to 'remember' the state of the line so it can recognise when it has been changed. The Code sketch in Listing 2 shows how this can be done.

Listing 2

```
 /* Simple LED and button example. Uses an external button
 connected to pin-12 to toggle the state of an LED connected to
pin-13
 */

 int inButton = 12;  // Switch connected to digital pin-12
 int outLED = 13;    // LED connected to digital pin-13

 boolean LEDstate = LOW;
 boolean buttonState = HIGH;
 boolean lastButtonState = LOW;

 void setup() {
   pinMode(inButton, INPUT);  // Button is an input
   pinMode(outLED, OUTPUT);   // LED  is an output
 }

 void loop() {
   buttonState = digitalRead(inButton);
   if (buttonState == LOW && lastButtonState == HIGH) {
     if (LEDstate == LOW){
       LEDstate = HIGH;
     }
     else
     {
       LEDstate = LOW;
     }
   }
 digitalWrite(outLED, LEDstate);
 lastButtonState = buttonState;
 }
```

Adding some sound

Now let's add some sound to our application so that an audible warning will be generated whenever the button is being pressed. We will need to add a miniature loudspeaker to the circuit and breadboard layout, as shown in Fig.1.19 and 1.20. The loudspeaker (LS1) is connected to Digital I/O pin-11. R3 is connected in series with the loudspeaker in order to minimise the current drawn from the Uno. R3 can be reduced to 220Ω or 100Ω in order to increase the volume of sound produced by the loudspeaker – see Listing 3.

Listing 3

```
/* Simple LED and button example. Uses an external button
connected to pin-12 to operate an LED connected to pin-13
and a small loudspeaker connected to pin-11
*/

int outSpeaker = 11;// Speaker connected to digital pin-11
int inButton = 12;  // Switch connected to digital pin-12
int outLED = 13;    // LED connected to digital pin-13

boolean LEDstate = LOW;

void setup() {
  pinMode(inButton, INPUT);     // Button is an input
  pinMode(outLED, OUTPUT);      // LED  is an output
  pinMode(outSpeaker, OUTPUT); // Speaker as output
}

void loop() {
  if (digitalRead(inButton) == LOW)
  // button has been pressed so turn the LED
  // 'on' and send tone signal to the speaker
  {
    LEDstate = HIGH;
    digitalWrite(outLED, LEDstate);
    tone(outSpeaker, 700);
  }
  else
  // button has been released so turn the
  // LED 'off' and stop sending the tone
  // signal to the speaker
  {
    LEDstate = LOW;
    digitalWrite(outLED, LEDstate);
    noTone(outSpeaker);
  }
}
```

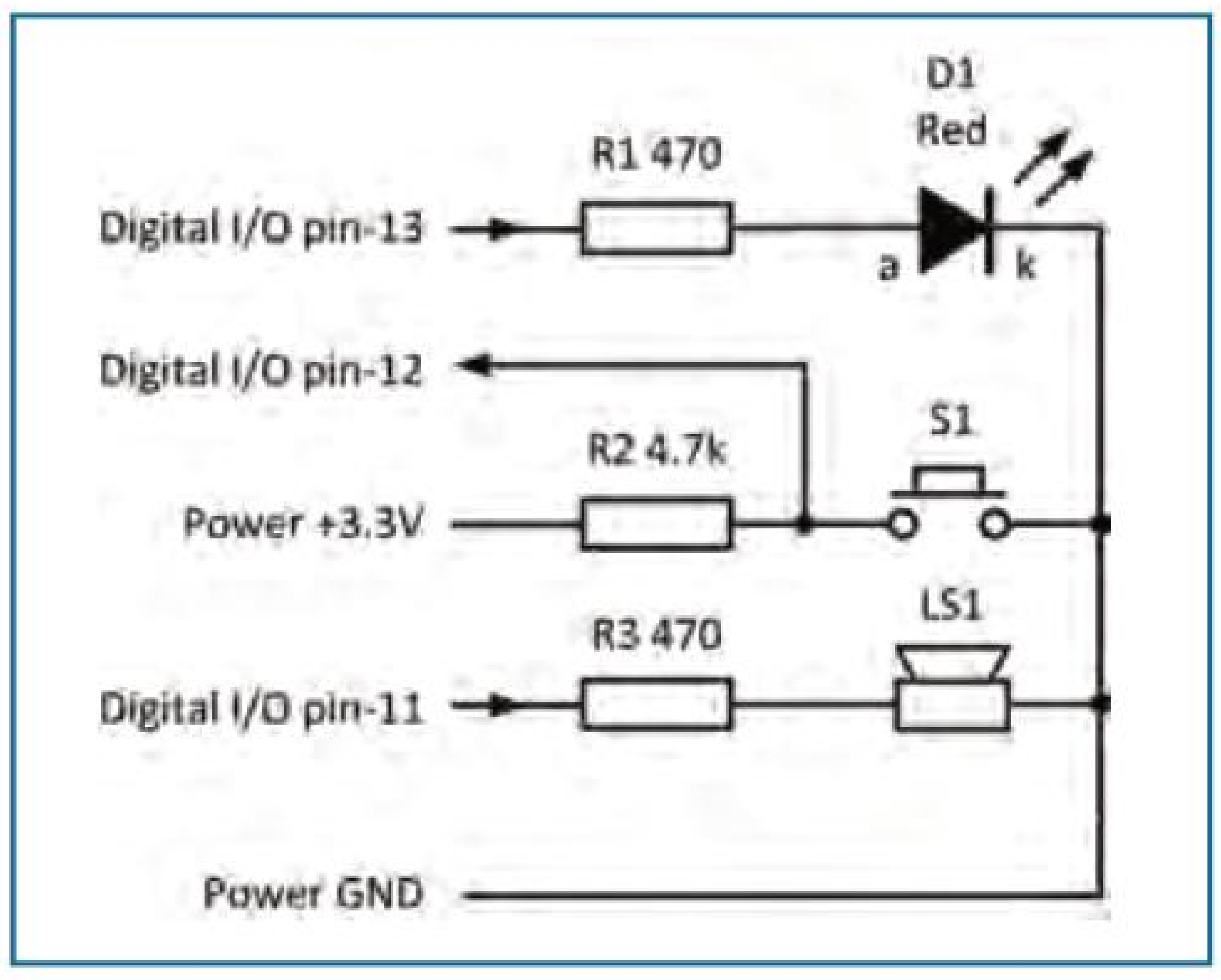


Fig.1.19. Circuit of the LED and switch interface with added loudspeaker

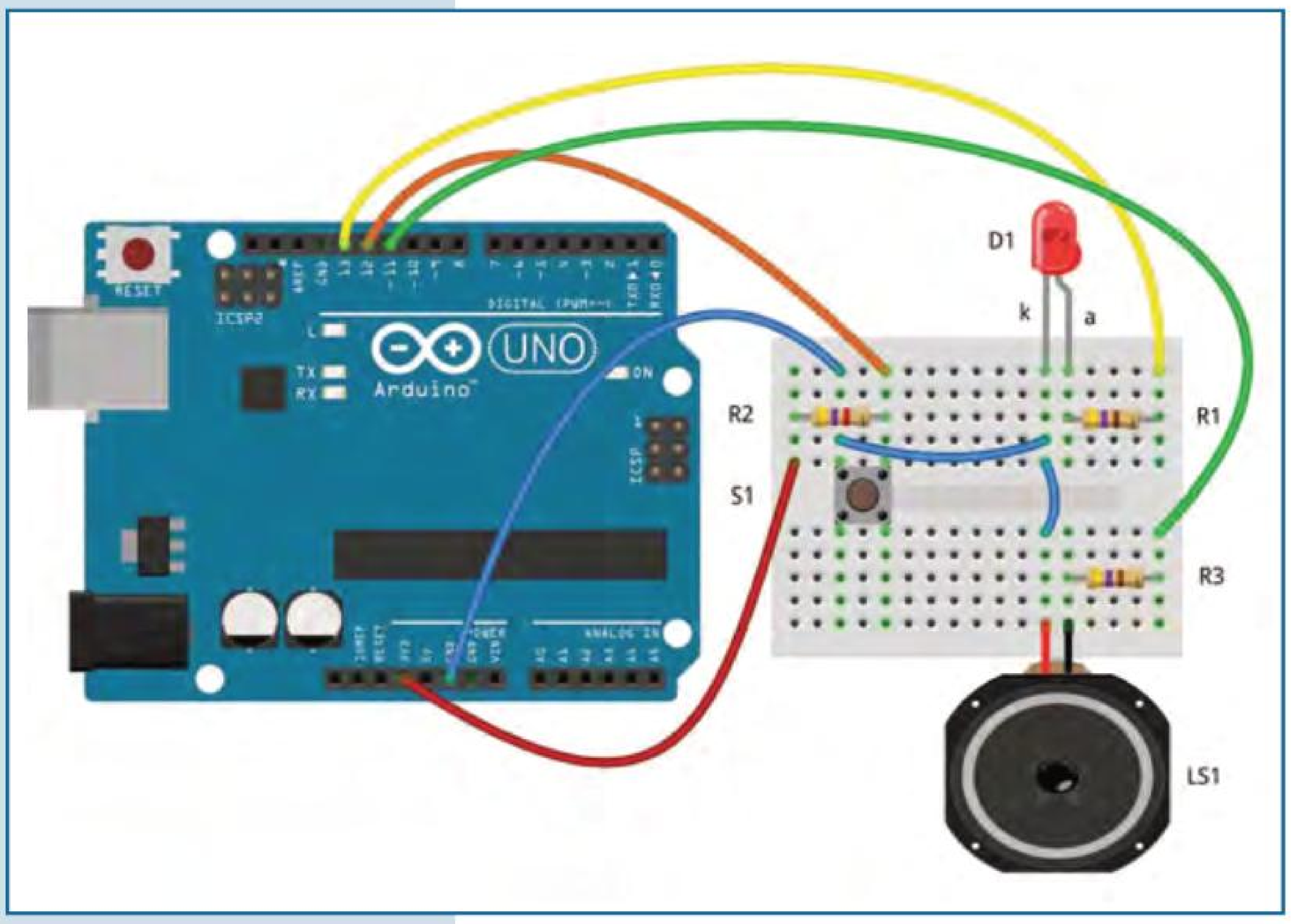


Fig.1.20. Fritzing breadboard arrangement for Fig.1.19

Coding Quickstart : Understanding data types

As you've already seen, in order to get your Arduino microcontroller hardware to do something useful you need to have code that will tell it what to do and how to respond when something happens. The process of producing code (ie, 'coding') is not particularly difficult, but it does require a structured and systematic approach. If you've ever had to provide someone with a detailed set of instructions for travelling somewhere you will know how important it is not to forget any steps and how to give your instructions in a clear and unambiguous way. The same applies to computer coding, but with the added complication that we need to present our instructions in a way that can be interpreted by a machine rather than a human being. Coding is easy to learn provided that you 'start simple' and build up your skills progressively and systematically. We start this month with a look at the ways in which data in the Arduino is handled and manipulated.

Boolean data

Data that can only take one of two possible values is referred to as 'Boolean data'. Inside the Arduino this type of data can be represented using a single byte (8-bits) of data and it can take a value of either TRUE or FALSE, HIGH or LOW or simply 'on' and 'off'. These two states are mutually exclusive and we refer to them as Boolean because they conform to the rules of Boolean Logic (much more of this in a later instalment).

The variables that we use in our code need to be declared before they can be used. An example of a Boolean declarations is as follows:

```
boolean powerGood = FALSE;     // power status
```

At some later point in the code (within the main loop that executes forever) you might encounter the following line:

```
powerGood = !powerGood;       // toggle the power status
```

Note that the '!' in the foregoing code fragment can be read as 'not' and the line of code simply changes the state of the Boolean variable to the opposite of what it was before. In other words, if `powerGood` had previously been HIGH it will become LOW, and vice versa.

Unfortunately, there's some potential for confusion here. The Arduino uses a byte (8-bits) of memory to store Boolean data, but since Boolean data can only exist on one of two possible states and where available memory is limited (as it is with the Arduino) it would be advantageous to use just a single bit of data rather than an entire byte because seven of the eight bits used to store the Boolean data are just not being used (a stored binary value of 0000000 will be interpreted as FALSE and anything else will be interpreted as TRUE). This is rather wasteful and so it's important to remember that using a Boolean data type is no more efficient in terms of memory usage than using integer values (see later). That said, it can often be rather neat and convenient to use Boolean data types.

Integer data

Whole numbers (numbers with no decimal point) are frequently stored as integers (or 'ints'). Integers require two bytes (16 bits) of storage and the most significant bit (MSB) is used to indicate the sign of the number. When this bit is 0 the value is positive and when it is 1 the value is negative. The method of representing numbers is referred to as two's (or 2's) complement notation and with 16-bits of data it yields a range that extends from –32768 to +32767. A typical extract from a program's setup code might be as follows:

```
int powerLED = 11;    // Output pin used for the
                      // power good LED
```

This line of code defines and initialises a variable that we've named powerLED. We've told the Arduino that it is to be handled as an `int` (ie, an integer) and that it is to be given an initial value of 11. The statement ends with a semicolon (;) and this is followed by a brief comment designed to act as a reminder of what the purpose of the statement is. Brief comments like this can be invaluable later on when the time comes to do some software maintenance and also when code is shared among several authors.

Later on in the program code you might find a line of the following form:

```
digitalWrite(powerLED, HIGH);  // Illuminate the
                               // power good LED
```

Even if you've never done any coding before you can probably make a reasonable guess of what this statement does. At another point in the code you might find something like this:

```
if(powerGood = = FALSE) {
   digitalWrite(powerLED, LOW);
}
```

The above code fragment turns the 'power good' LED off when the system has sensed a problem with the power supply. It does this by examining the state of the powerGood Boolean variable (see earlier) and, if found to be FALSE (in other words, not good) the 'power good' LED is turned 'off' by writing a low (0V) to its digital output pin (pin-11 as defined within the integer declaration earlier in the code).

The syntax for the declaration (in this particular case it's a constant rather than a variable) is simply the name followed by the value that you've assigned to it. Note that the name takes the form of a meaningful description (two words with no space included between them). Note also that the first word begins with a lower-case character and the second word with a single upper-case character. This convention helps make the code easier to read and it avoids the need to include a space character in the name (which would be invalid).

At some point later in the code you might find something like this:

```
if(powerGood = = FALSE) {
   digitalWrite(powerLED, LOW);
}
```

There's often a need to increment or decrement a variable within a program loop (for example, when counting events) but, because of the use of two's complement notation, it is very important to be aware that when a variable is incremented or decremented the value will roll-over whenever it reaches the maximum allowable size. So, for example, incrementing 32767 (the maximum allowable positive value) will cause the value to become –32768 (note the change of sign). In a similar manner, decrementing a value of –32768 (the maximum allowable negative value) will cause a variable to take a new value of +32767.

Finally, please be aware that the use of two bytes to store an integer is not consistent over all Arduino versions. For example, the Arduino Due uses four bytes (32-bits) to store integer values. This provides a range of values extending from –2,147,483,648 to +2,147,483,647.

Floating point data

As the name implies, floating point numbers, or 'floats', are numbers that include a decimal point. They offer a much larger range from $-3.4028235 \times 10^{38}$ to $+3.4028235 \times 10^{38}$. Floats are stored using four bytes (32 bits) of data.

Floats are often used to represent analogue values from sensors. Due to the need for four bytes of data, floating point maths can be significantly slower than when integers are used (where only two bytes of data are involved). Consequently, it is advisable to use integers rather than floats whenever speed of execution is important.

A typical extract from a program's setup code might be:

```
float peakConvert = 1.4142;    // To convert from
                               // RMS to peak
```

We could then determine the peak voltage and peak current present in a 50Ω load using something of the form:

```
peakVoltage = rmsVoltage * peakConvert;
peakCurrent = peakVoltage / 50;
```

Byte data

Byte data stores 8-bits of data as unsigned binary numbers. So, for example, a binary value of 10000001 (equivalent to 81 in hexadecimal or 129 in decimal) might be defined as follows:

```
byte bitMask = 0x81; // mask unwanted bits
```

Note that the `0x` prefix denotes a value expressed in hexadecimal (base 16) format. Because only eight bits are used, byte data is limited in range. The minimum value that can be represented is 0 when all of the bits are 0 (hexadecimal 0x00) and the maximum value is 255 (hexadecimal 0xFF) when all of the bits are set to 1. Despite the restricted range, byte data can be useful in a variety of applications, particularly when dealing with the status of byte-wide (ie, eight-bit) input or output lines. For example:

```
byte inputStatus = 0x00;     // initialise
                             // input port status
byte inputFailure = 0xFF;    // all port lines
                             // have gone high
```

At some later point in the code we might encounter a line of the form:

```
if(inputStatus = = inputFailure) {
   Serial.print(“Warning: Input failure!”);
}
```

In this example, a fault is present if all of the input lines are simultaneously in the HIGH state and in this condition the value of the `inputStatus` variable will be `0xFF`, If this condition is detected a brief warning message will be sent from the Arduino's serial port.

Character data

The character data type is used when we just need to represent alphanumeric information such as plain text. The character data type uses a single byte of memory to store each character. Thus, the word 'character' would need nine bytes of storage. Character literals are enclosed within single quotes (eg, 'A') while double quotes are used for strings comprising several characters (eg "Arduino").

Character data is encoded using the American Standard Code for Information Interchange (ASCII). Each character is represented by a corresponding signed 8-bit value. 'A' for example is encoded as 01000001 in binary. This is equivalent to 41 in hexadecimal or 65 in decimal 65. The basic ASCII character set uses only seven bits (equivalent to a decimal range that extends from 0 to +127. When the leading bit is set (ie, 1 and not 0) the signed byte becomes negative with a range extending from –1 to –128. These 128 values can be used to represent special characters.

Note that each of the following three lines of code are equivalent:

```
char testChar = ‘A’;
char testChar = 65;
char testChar = 0x41;
```

Note how the number base in the last example is indicated by the prefix `0x` which indicates that the number that follows is written in hexadecimal format.

The `Serial.println()` function provides you with a way of printing data using several different representations, as shown in the following code:

```
Serial.println(analogValue);          // print ASCII character
Serial.println(analogValue, DEC);     // print as ASCII-encoded
                                      // decimal
Serial.println(analogValue, HEX);     // print as ASCII-encoded
                                      // hex
Serial.println(analogValue, OCT);     // print as ASCII-encoded
                                      // octal
Serial.println(analogValue, BIN);     // print as ASCII-encoded
                                      // binary
```

You will find an example of the use of serial printing in this month's *Arduino World*. This concludes our brief look at the way that data is represented in an Arduino environment. Next month, we will get to grips with decisions and how to make them, as well as explaining how program code is structured and laid out.

Arduino World : Getting started with an UnoArduSim

If you don't have an Arduino to hand you can still develop and test your code with a variety of virtual I/O devices using an Arduino simulator and one of the best of these is UnoArduSim, an excellent freeware real-time simulator developed by Dr Stan Simmons at Queen's University in Ontario, Canada.

UnoArduSim is designed for the student and Arduino enthusiast. It allows you to experiment with, and to easily debug Arduino programs without the need for any physical hardware devices. You can choose from a variety of virtual I/O devices, configure and connect them to a virtual Arduino Uno using the Lab Bench Pane. There's no need to worry about wiring errors, misconnections or faulty devices while developing your code.

UnoArduSim provides simple error messages for any parse or execution errors it encounters, and allows debugging with Reset, Run, Run-To, Halt, and flexible stepping in the Code Pane. This provides a simultaneous view of all global and currently-active local variables, arrays, and objects in the Variables Pane. Run-time array-bounds checking is provided, and internal RAM overflow will be detected and the culprit program line highlighted. Any electrical conflicts with attached I/O devices are flagged and reported as and when they occur.

Arduino source code files (INO or PDE) are loaded into the program Code Pane. The program is then parsed, and 'compiled' into a tokenised executable which is then ready for simulated execution (note that, unlike the Arduino's Integrated Development Environment, a standalone binary executable is not created). Any parse errors are detected and flagged by highlighting the line that failed to parse, and reporting the error on the status bar at the very bottom of the UnoArduSim application window. This is an extremely useful feature.

An Edit/View window can be opened to allow you to see and edit a syntax-highlighted version of your user program. Errors during simulated execution (such as mismatched baud rates) are reported on the status bar, and via a pop-up message box.

UnoArduSim V1.1 is a substantially complete implementation of the Arduino programming language V1.0.6, as documented on the official Arduino website. While UnoArduSim does not support the full C++ implementation present in the Arduino IDE and its underlying GNU compiler, it is likely that only the most advanced programmers would discover something they wished to use was missing. It is usually possible to avoid problems with simple work-arounds.

Because UnoArduSim is a high-level-language simulator, only C/C++ statements are supported – assembly language statements are not. Similarly, because it is not a low-level machine simulation, ATmega328 registers are not accessible for either reading or writing, although register-allocation, passing and return are emulated when selected from within the Options menu. UnoArduSim is currently only available for the Windows platform, but porting the software to Linux, MacOS or Java might be a project for the future. You can download the installation software from: **https://www.sites.google.com/site/unoardusim/services**

Finally, Fig.1.21 shows UnoArduSim running a sketch that displays a table of ASCII character data (see *Coding Quickstart*) with the program's output displayed using the Serial Monitor window – see Listing 4.

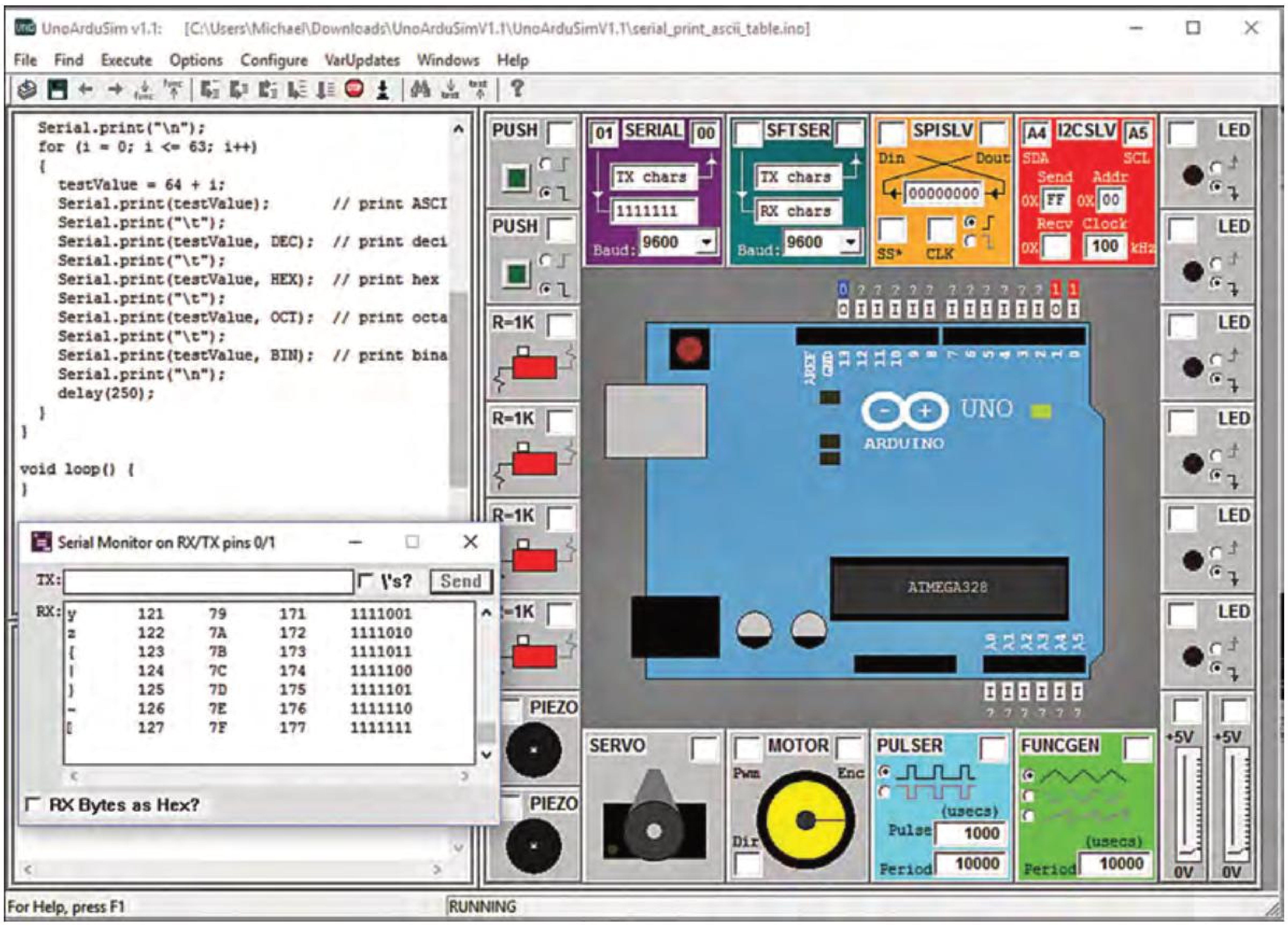
Next month

In next month's *Teach-In 2016* we will look at methods of connecting real-world hardware. To this end, *Arduino Workshop* deals with driving external loads, while *Arduino World* looks at a range of shields and add-on interface

Listing 4

```
/* Use serial printing to produce an ASCII table with
values shown in decimal, hex, octal and binary
*/

int i; // loop counter
char testValue;

void setup() {
      // open the serial port at 9600 bps:
      Serial.begin(9600);
      Serial.print(“ASC”);
      Serial.print(“\t”);
      Serial.print(“Dec”);
      Serial.print(“\t”);
      Serial.print(“Hex”);
      Serial.print(“\t”);
      Serial.print(“Oct”);
      Serial.print(“\t”);
      Serial.print(“Bin”);
      Serial.print(“\n”);
      for (i = 0; i <= 63; i++)
      {
            testValue = 64 + i;
            Serial.print(testValue);       // print ASCII char
            Serial.print(“\t”);
            Serial.print(testValue, DEC);  // print decimal
            Serial.print(“\t”);
            Serial.print(testValue, HEX);  // print hex
            Serial.print(“\t”);
            Serial.print(testValue, OCT);  // print octal
            Serial.print(“\t”);
            Serial.print(testValue, BIN);  // print binary
            Serial.print(“\n”);
            delay(250);
      }
}

void loop() {
}
```

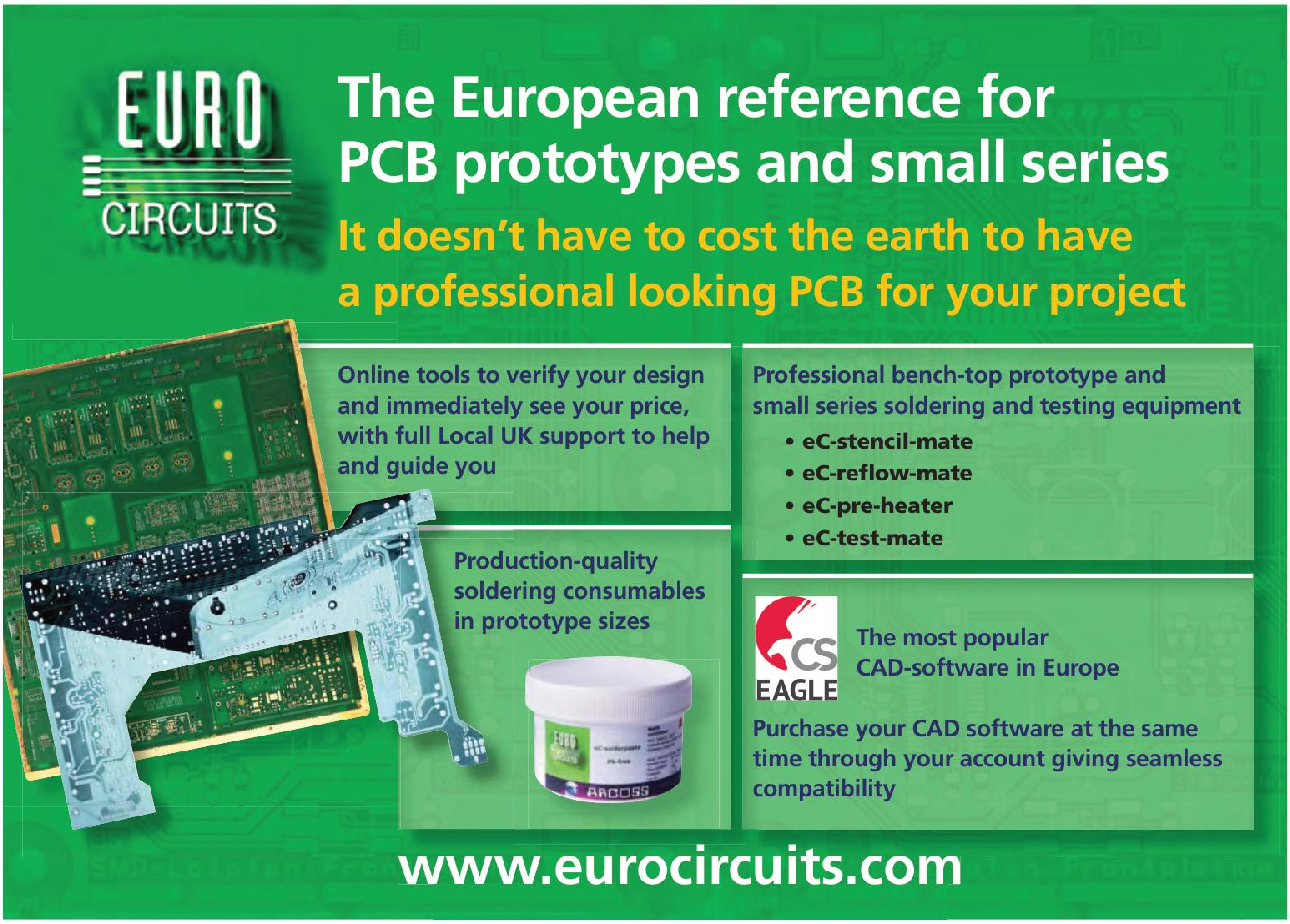
boards that will allow you to drive high-current and high-voltage loads, such as mains-operated lamps and motors. *Coding Quickstart*, our regular programming feature, we will be explaining the structure and layout of program code, as well as introducing decisions and how to make them. Finally, *Get Real* will show you how to design and construct an Arduino-based door/window security system.


UnoArduSim v1.1: [C:\Users\Michael\Downloads\UnoArduSimV1.1\UnoArduSimV1.1\serial_print_ascii_table.ino]
File Find Execute Options Configure VarUpdates Windows Help
PUSH
PUSH
R=1K
R=1K
R=1K
R=1K
PIEZO
PIEZO
SERIAL
SFTSER
SPISLV
I2CSLV
LED
SERVO
MOTOR
PULSER
FUNCGEN
UNO
ARDUINO
ATMEGA328
Serial Monitor on RX/TX pins 0/1
TX:
\'s?
Send
RX:
RX Bytes as Hex?
For Help, press F1
RUNNING

```
  Serial.print("\n");
  for (i = 0; i <= 63; i++)
  {
    testValue = 64 + i;
    Serial.print(testValue);        // print ASCI
    Serial.print("\t");
    Serial.print(testValue, DEC);  // print deci
    Serial.print("\t");
    Serial.print(testValue, HEX);  // print hex
    Serial.print("\t");
    Serial.print(testValue, OCT);  // print octa
    Serial.print("\t");
    Serial.print(testValue, BIN);  // print bina
    Serial.print("\n");
    delay(250);
  }
}

void loop() {
}
```

```
y       121     79      171     1111001
z       122     7A      172     1111010
{       123     7B      173     1111011
|       124     7C      174     1111100
}       125     7D      175     1111101
~       126     7E      176     1111110
[       127     7F      177     1111111
```

Fig.1.21. UnoArduSim running the ASCII table sketch with the program's output displayed in the Serial Monitor window


EURO CIRCUITS

The European reference for PCB prototypes and small series

It doesn't have to cost the earth to have a professional looking PCB for your project

Online tools to verify your design and immediately see your price, with full Local UK support to help and guide you

Professional bench-top prototype and small series soldering and testing equipment
- eC-stencil-mate
- eC-reflow-mate
- eC-pre-heater
- eC-test-mate

Production-quality soldering consumables in prototype sizes

CS EAGLE

The most popular CAD-software in Europe

Purchase your CAD software at the same time through your account giving seamless compatibility

www.eurocircuits.com

NET WORK

by Alan Winstanley

The domain name game

THIS month's *Net Work* starts with a fresh look at the domain name market and how to register a domain for yourself, also checking out the latest domain name suffixes that are now available.

It was foreseen decades ago that as the popularity of the Internet increased, the pool of available IP addresses – those unique numerical strings that identify users on the network – would eventually dry up. Current IPv4 addresses are seen in the familiar dotted-quad format (eg, 87.123.227.130) but gradually IPv6 addresses are starting to appear too. These contain eight groups of four hex characters, which should make IP address allocation scalable for the foreseeable future. Remember to check for future-proof IPv6 compatibility when buying new routers or network hardware today, as IPv6 is likely to become an issue within the next few years.

It's the job of the DNS (domain name system) to translate a human-recognisable string like `www.epemag.com` or `mail.wimborne.co.uk` into its corresponding IP address. Domain names like `wimborne.co.uk` all end with a top-level domain or TLD (`.uk` being a country-code TLD or ccTLD) and so-called generic TLDs (gTLD) include the familiar `.com`, `.org` and `.net` domains. A full listing of TLDs – everything from `.aaa` to `.zw` – is at: **https://www.iana.org/domains/root/db** and, in case you ever wondered, the entire list of country codes to ISO 3166-1 is also searchable at the International Standards Organisation (ISO) website via **www.iso.org/iso/country_codes**

In earlier days, the choice of domains was fairly restricted: while owning a dot.com had a certain kudos or ring about it, Brits might choose a `.co.uk` instead, or perhaps a `.org` or `.net` generic domain might have a less corporate feel. As commercialisation has inexorably taken over, the range of TLDs has skyrocketed and 'sponsored' or branded TLDs such as `.apple`, `.bbc` and `.lamborghini` are now held by their respective rights owners.

Woolly thinking

Anyone wanting to buy a new domain name will probably find that that their preferred choice has already been taken, as every combination of initials, everyday nouns, adjectives and surnames was snapped up long ago. It may be worth checking that trademarks are not being infringed too, as the former owner of **baa.com**, a website devoted to sheep, found out to his cost when the British Airports Authority (BAA) famously went legal before acquiring the name for itself. Sometimes opportunistic speculators would buy domains and 'squat' on them, ever hopeful of reselling them to interested parties. This could backfire badly, as the celebrated UK case of One in A Million Ltd demonstrated in 1998. The speculators had registered the names of many well-known British companies, such as **bt.org**, **burgerking.co.uk** and even **tandy.co.uk**, **tandy.net** and similar domains, which they offered to sell to Intertan UK for £15,000. The Appeals Court upheld that these registrations infringed the rights of their corresponding business owners and One in a Million lost the lawsuit. More useful advice on the legalities (UK) of domain name registration is available at the UK law firm website: **www.out-law.com/page-5700**

Existing domains are frequently traded, and one of the world's largest sources of 'pre-owned' domains is Sedo (**www.sedo.com**) where 13 million domains are open to offer: the domain **wood.com**, for example, is a snip at $700,000, but you might find something more in tune with your particular budget!

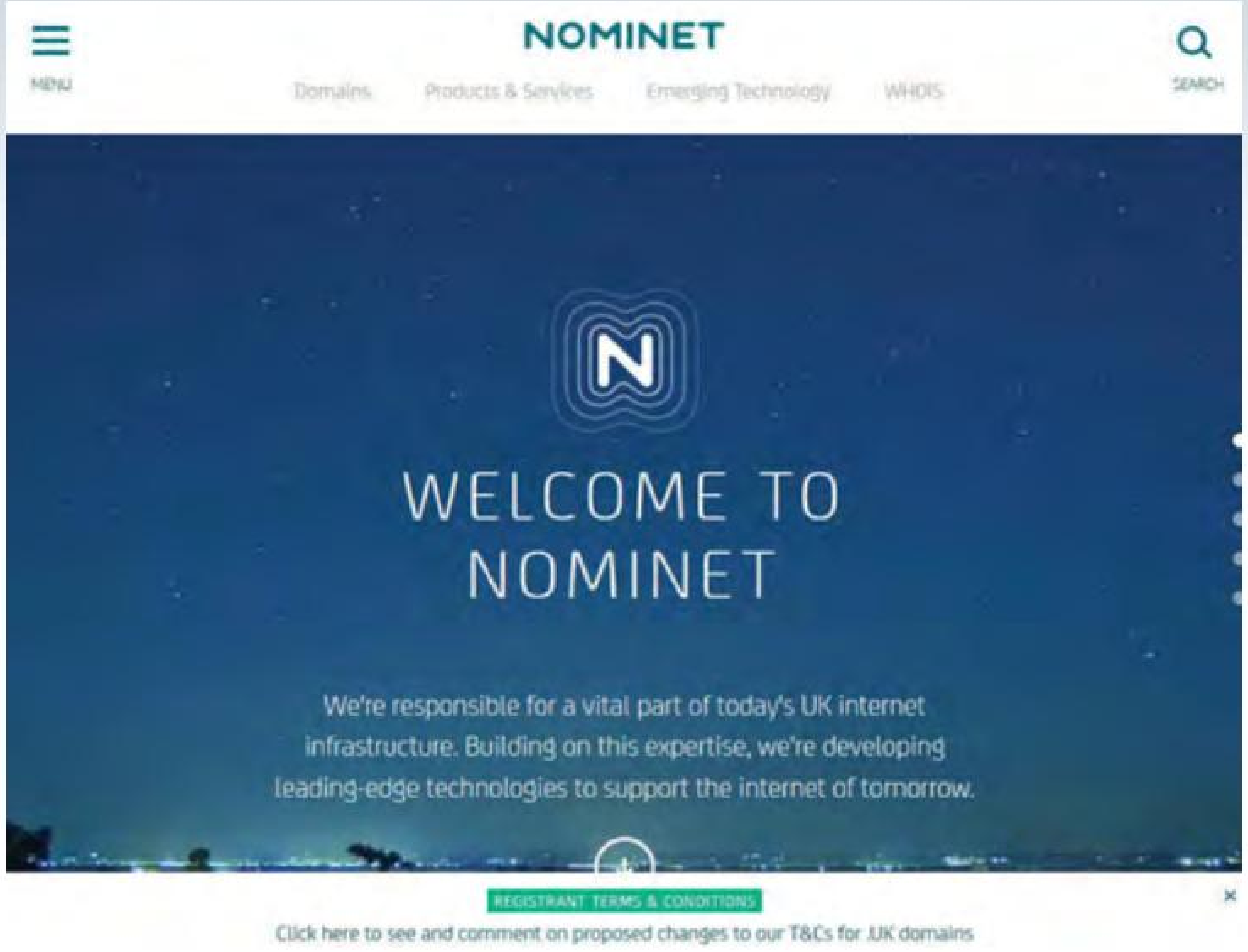
If you acquire your own domain name (making you the 'Registrant') it is worth remembering that you never have legal ownership *per se*, but are merely renting it for as long as you pay the registration fees. Thus, domain names can be like dollar nuts and bolts holding up a tower block, and forgetting to renew them is something that has happened even to large conglomerates. In 2008, the Emirates airline forgot to renew its domain and it lapsed on the very day that it was expecting its first Airbus A380 super jumbo-jet, and it wanted to broadcast a *fanfaronade* on its website. Renewal dates are definitely ones to highlight on your calendar, or better still set them to renew automatically (provided you remember to keep your payment details up to date too!). Keep a look out for those renewal notices, as the longer you overlook a lapsed domain, the harder it will be to recover it afterwards.

It's crucial that the domain's registration details are maintained properly with an up-to-date email address that you check routinely. This factor is constantly overlooked, meaning ISPs or domain name Registrars cannot contact you to ensure domain renewals or transfers are being addressed properly. Various contact details are also stored in the domain's WHOIS database record, which can be checked publically online. The deceitful practice of 'domain name slamming' involves another domain seller contacting you (via email or even by letter post) to state that your domain is due to expire (they checked the WHOIS) and reminding you to renew it immediately (with them); in reality they are trying to poach your business by worrying you into transferring it to another reseller unconsciously. Some domain name sellers offer WHOIS protection to disguise your details and protect your privacy; this can stop anyone looking up the ownership details of a dot-com or dot-net, for example.

Non-commercial owners of `.uk` domains can protect their privacy by applying to hide their contact information from the Nominet database, though your name will still appear in it. For example, try looking for `arw.me.uk` using the Nominet WHOIS lookup at: **www.nominet.uk/whois**. Those who use generic domains like dot-coms can buy WHOISGuard protection, sold by Namecheap for example, to withhold the ownership details.

Pick your own domain

Today it has never been easier to pick from a huge range of other names due to the gradual release of new generic TLDs in the past two years. These include: `.plumbing`, `.london`, `.irish`, `.technology` and `.solar` and many



WELCOME TO NOMINET

We're responsible for a vital part of today's UK internet infrastructure. Building on this expertise, we're developing leading-edge technologies to support the internet of tomorrow.

Click here to see and comment on proposed changes to our T&Cs for .UK domains

Nominet ultimately controls `.uk` *domain name registration. Sadly, its website has had a severe case of designer-itis*

more besides, which allows domain name owners to better match their own affiliation or locality.

Unfortunately, these recent new top-level domains are already being hijacked by spammers, and phoney hyperlinks utilising them now appear regularly in phishing emails meaning a visit to an infected website is still just a mouse-click away. A typical deceptive email arrived in the author's mail today, with a link to **paypal.com.views.services** which exploited the new **.services** TLD: no '`.com`' at the end, you'll notice. A sub-domain can be created 'underneath' a domain name so in this actual example, **com.views.services** was added as a sub-domain, and **paypal** was set up as a sub-sub domain.

The offending domain has since been repossessed by GoDaddy. However, when I recently alerted the UK's Nominet domain registration body about a fraudulent `.co.uk` domain being used in a phishing attack, their response was lamentable: if I wanted to do anything about it I should contact the police or apply for an interim court order myself! Further queries I made on legal domain name ownership were met with an equally muddled response. Nominet has been riven with top-level management problems and growing pains over the years, and their grossly overdesigned website is a prime example of a serious issue being trivialised, treating visitors like tablet users flicking around Facebook.

Domain name vendors such as GoDaddy, Namecheap and Britain's Names.co.uk can provide many generic TLDs, including the latest ones, along with email services and web server hosting if required. It is simply a case of opening an account and searching for a name, which then becomes yours to use for the registration period. Some cheap domains may look attractive but have a hidden exit penalty which locks you into that vendor's services unless you pay a release fee (say, £10) to move the domain elsewhere.

A number of extras can be bundled with domains, some of which can be quite taxing to set up. Depending on the package bought, POP3 or IMAP email boxes may be included, or perhaps 'mail forwarding' to another address of your choice may be possible. Domains can also be pointed towards other websites (domain web forwarding). Sub-domains may be allowed, and webspace and bandwidth can be purchased if needed. More complicated domain name setups involve changing the domain's DNS records, which needs some technical knowledge that may be better delegated to the ISPs technical support instead. Not all packages offer direct access to a domain's DNS records in any case. Britain's Names.co.uk offers online help at: **www.names.co.uk/support/1156-changing_your_domains_dns_settings.html** to give you a taste of what's involved in managing your domain's DNS.

The market for domain names has changed out of all recognition since the early days and users are no longer limited to a mere dot-com or .co.uk. A visit to one of the major domain sales websites will give you a good taste of the wide variety that is available today.

namecheap
Domains
Hosting
Apps
Security
Account
Search
Get Started
Namecheap for
Individuals
Business
Resellers

.XYZ for a Dollar

No kidding. New .xyz registrations are just $1. Get Yours →

New around here?

Create your pro web presence in no time.

Choose Your Name

Host Your Site

Build a Winner

Namecheap.com is one of several sellers of domain names and hosting services

Countdown to Zero

In January's *Net Work* I showed a cheap and cheerful Android HDMI dongle that could turn a spare monitor or TV into a decent Android 4.4-powered device, offering web and network access through the usual Android apps. The Wi-Fi / Bluetooth HDMI dongle worked as expected and proved surprisingly versatile, also letting me view my IP security camera video on my TV screen. I also mentioned Intel's Compute Stick, an HDMI device that runs as a Windows 8.1 or Windows 10 device in a fan-cooled dongle. Intel's PR showed no interest in my press enquiry, but I won't spend £80 or more just to test one, so unfortunately I could not review the Intel Compute Stick in this issue as I'd hoped.

Intel has also taken a battering with the news that the Intel Galileo, Intel's Arduino answer to the Raspberry Pi designed for education, makers and Internet of Things (IoT) applications, would no longer be supported by Microsoft after all. It does not meet the hardware requirements for Windows 10 IoT Core (see: **https://dev.windows.com/en-us/iot**). Instead, Raspberry Pi 2 takes the honours, and Microsoft states that wiring support is now available on Windows 10 IoT Core running on Raspberry Pi 2, allowing enthusiasts to migrate their existing Galileo projects to Windows that way.

Meanwhile, the latest Raspberry Pi Zero has debuted at just $5 cost price and this 65mm x 30mm board has already sold out several times. More details at: **https://www.raspberrypi.org/blog/raspberry-pi-zero**. Although it does not have networking built-in directly due to its price point, the Raspberry Pi Zero introduces computing and programming technology to everyone at a throwaway price. Looking back through some old archive issues of *Everyday Electronics*, the Raspberry Pi Zero is equivalent in real terms to the cost of a 74 TTL logic chip in the 1970s! Meantime, British schools await the new BBC micro:bit (**https://www.microbit.co.uk**) educational computer, which has been postponed for developmental reasons since last year. With so much exciting hardware now available, choosing and using network-capable modules has never been so rewarding for the electronics hobbyist. My thanks to *Chat Zone* user ***Cjay*** for the early heads-up on the Pi Zero.

Printing with Envy

In the mid-1990s, when USB made its first appearance on the Windows platform, it promised simple 'plug and play' connectivity, but the reality was often something very different. Some early USB peripherals were proper swines to install, and the writer has enough bitter experience of setting up USB printers and scanners to last a lifetime. Dodgy drivers and product underdevelopment frequently caused installation problems or conflicts that had to be sorted out in the field by helpless customers. The later addition of wireless networking made things trickier still. For starters, a Wi-Fi printer often needed installing on USB before it would work wirelessly (if you were lucky).

HP Envy 5540 all-in-one printer scanner; a pleasure to install!

A friend asked for help installing a new HP Envy all-in-one printer scanner. I admitted my experiences with some HP devices had been very mixed in the past, but I was willing to give it a go. The printer was unboxed, two cats were shooed out of the way and I rummaged around looking for its USB lead: there wasn't one. Simply plug it into the mains and switch on, the guide said, so that's what I did while quaffing a mug of tea and setting up two printer cartridges. I would soon find that the pint-sized printer had some tricks up its sleeve and the installation process proved to be a delight: by default it found the wireless network and hooked itself onto the LAN without any problem. No need to scramble around and input the network details. The printer LCD displayed a web link that I punched into the nearby laptop and 30 seconds later the printer and scanner software was up and running. The HP Envy then printed a cartridge alignment pattern that was scanned in again, setting up the ink cartridges in a totally seamless process. Next, a visit to Apple's app store fetched the HP All In One Remote app onto the user's iPhone, and it also popped up automatically on her iPad without any intervention. Consequently, the user could now print effortlessly from a tablet or smartphone over the wireless network. The new machine also scanned direct to PDF or to email, always a handy timesaving feature.

It doesn't stop there, as the HP printer also provides for cloud printing and document sharing over the web. In theory, the user could send images or documents to the printer from anywhere in the world. Anyway, the first job was to print off the owner's aircraft boarding pass that had been downloaded for a forthcoming vacation, so we will doubtless see very soon how well cloud computing performs in reality! All in all, it was a rewarding and painless installation and was a good result all round – technology doing what it's supposed to do.

That's all for this month's *Net Work*. I'm always glad to hear from readers and I can be contacted at **alan@epemag.demon.co.uk**. Comments for possible inclusion in *Read Out* can be sent to **editorial@wimborne.co.uk**

Laser *Why tolerate when you can automate?*

X-10 *Home Automation*

KAT5 AV transmission and IR control system

Barix Ethernet based MP3, communications and control systems

www.laser.com

Integrators, Installers, Trade and Retail customers welcome

C-Bus Shop

C-Bus and C-Bus Wireless

www.cbus-shop.com

Laser Business Systems Ltd
Tel: +44 (0) 20 8441 9788
Fax: +44 (0) 20 8449 0430
Email: info@laser.com
16 Garthland Drive, EN5 3BB

pico Technology

PC OSCILLOSCOPES

PicoScope News

PicoScope 6.11 is now released

UPGRADE NOW FROM

www.picotech.com/downloads

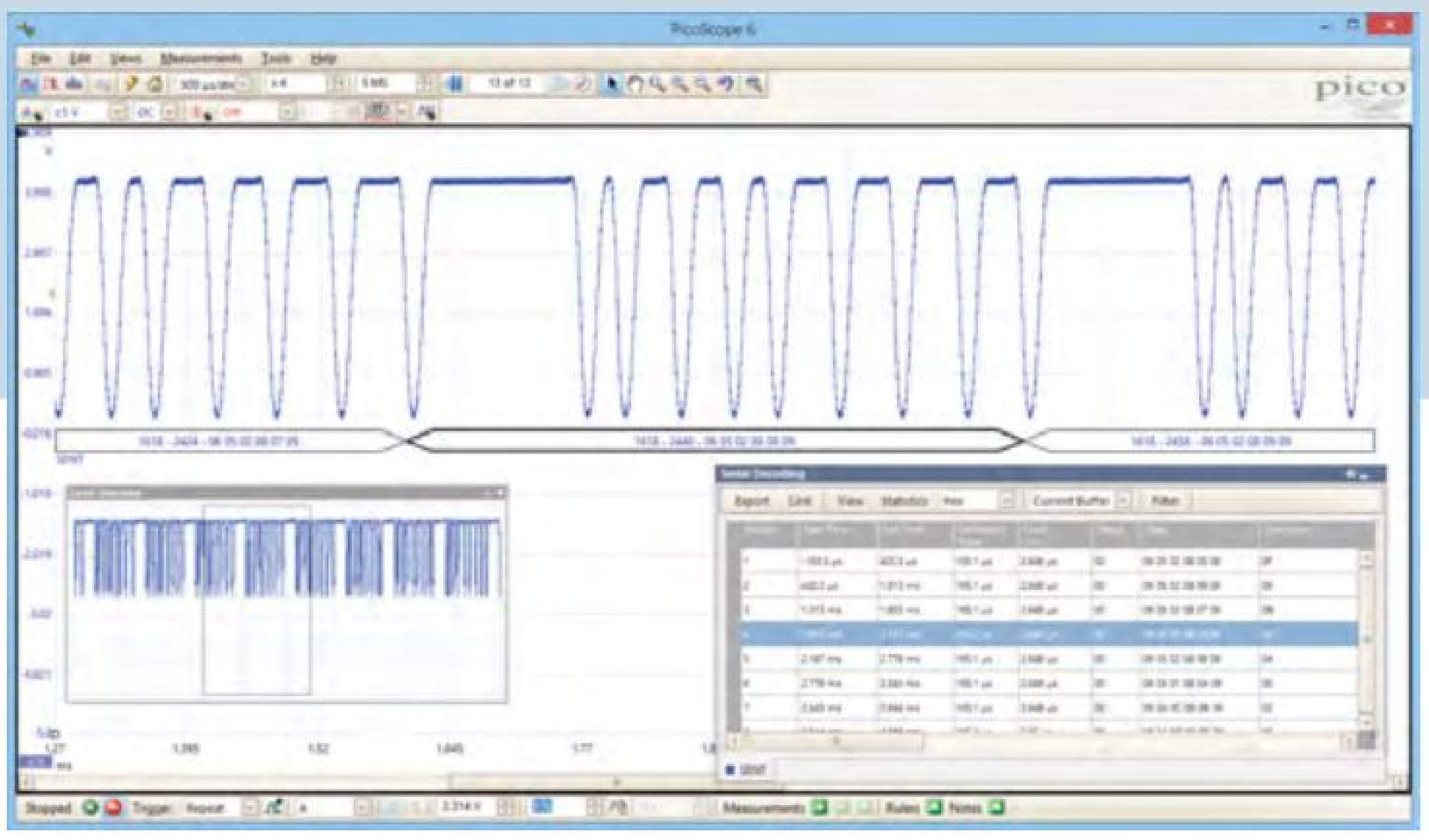
PicoScope Good News

GREAT NEW FEATURES INCLUDING:

- **16 serial protocols supported as standard:**

Automotive: CAN, FlexRay, LIN, SENT
Avionics: ARINC 429
Computer: Ethernet 10Base-T, 100Base-TX, PS/2, UART (RS-232, RS-442, RS-485), USB (FS, HS)
Embedded systems: 1-Wire, I2C, I2S, SPI
Lighting: DMX512 **Hobby:** DCC

- **Touchscreen functionality**
- **Mathematical waveform processing tools**
- **Frequency and duty-cycle v time plotting**
- **Advanced waveform mathematics now include user-configurable filters: High Pass, Low Pass, Band Pass and Band Stop**



PicoScope Best News

ALL FOR FREE

All PicoScope users old and new can upgrade to the latest software for free, for the life of their product. You can also download the full software to try it for yourself in demo mode.

www.picotech.com/PS448

By Robert Penfold

INTERFACE

BASIC printer port interfacing

PART of the previous *Interface* article was devoted to some of the so-called legacy ports that are reappearing on some modern PCs, and their possible use for simple interacting projects. I do not intended to dwell in the past, but this month's article will look at one of these legacy ports, the printer port, in more detail. The RS232C serial port, with its ability to hand simultaneous two-way communication is in some ways more potent than the parallel port. However, it is relatively slow, tends to require more complex interfacing, and is notorious for the problems that are often encountered when trying to use it for even fairly simple applications.

The parallel port is the simpler of the two for basic interfacing. Although the original PC parallel port only provided an 8-bit output plus some handshake lines, any modern type can be set to use the eight data lines as inputs or outputs. Unfortunately, individual direction control is not provided, and all eight lines must be set as inputs, or as outputs. Even so, the parallel port can be used to interface a PC to a wide range of devices, and in general it is free from problems.

Practise safe interfacing

It has to be pointed out that due care has to be taken when interfacing you own devices to a PC via a legacy port. There are often built-in buffer stages between the port's input/output lines and the main electronics of the PC, but this might not be sufficient to prevent expensive damage if a serious error is made. Avoid short-circuiting outputs, using excessive input voltages, or anything else that has the potential to cause damage. It also has to be emphasised that direct control of a printer port requires it to be a built-in type that appears in the computer's input/output address map. Some sort of USB or PCI add-on port will not suffice.

There is no supply pin on the printer port, and power for any add-ons that use this port must be obtained from elsewhere. One option is to obtain +5V from the supply output of a USB port, or another is to power the add-on from a battery. These are both safe options, but there can be problems if the add-on has its own mains power supply. Desktop PCs usually have their chassis earthed to the mains earth, and there should be no problems if the add-on device also has an earthed chassis. Things become more risky if the PC is a laptop or other portable PC that is powered from the mains via a double-insulated adapter that does not use an earth connection. Similarly, it is risky to use an add-on that is powered via a mains adapter or other mains power supply that uses double insulation and no earth connection.

The problem is that a high voltage can exist between the 0V supply of the computer and the 0V supply of the add-on. Although this will be at a high impedance and unable to supply much current, it could be more than sufficient to do serious damage to the PC and/or the add-on circuit. In the dim and distant past I did some serious damage to a home computer by ignoring this risk. If one or both of the units in the system have a double-insulated mains power supply, opto-isolators or some other form of protection circuit must be included to prevent damage to the circuits.

In the mode

By default, it seems to be the norm for the printer port of a modern PC to be switched off. It is necessary to go into the BIOS Setup program and switch the port on before it can be used. Presumably things are done this way so that a port that might never be used does not waste the computer's resources. Even if the printer port is active by default, it is still a good idea to go into the BIOS Setup program to ensure that it is in the correct operating mode.

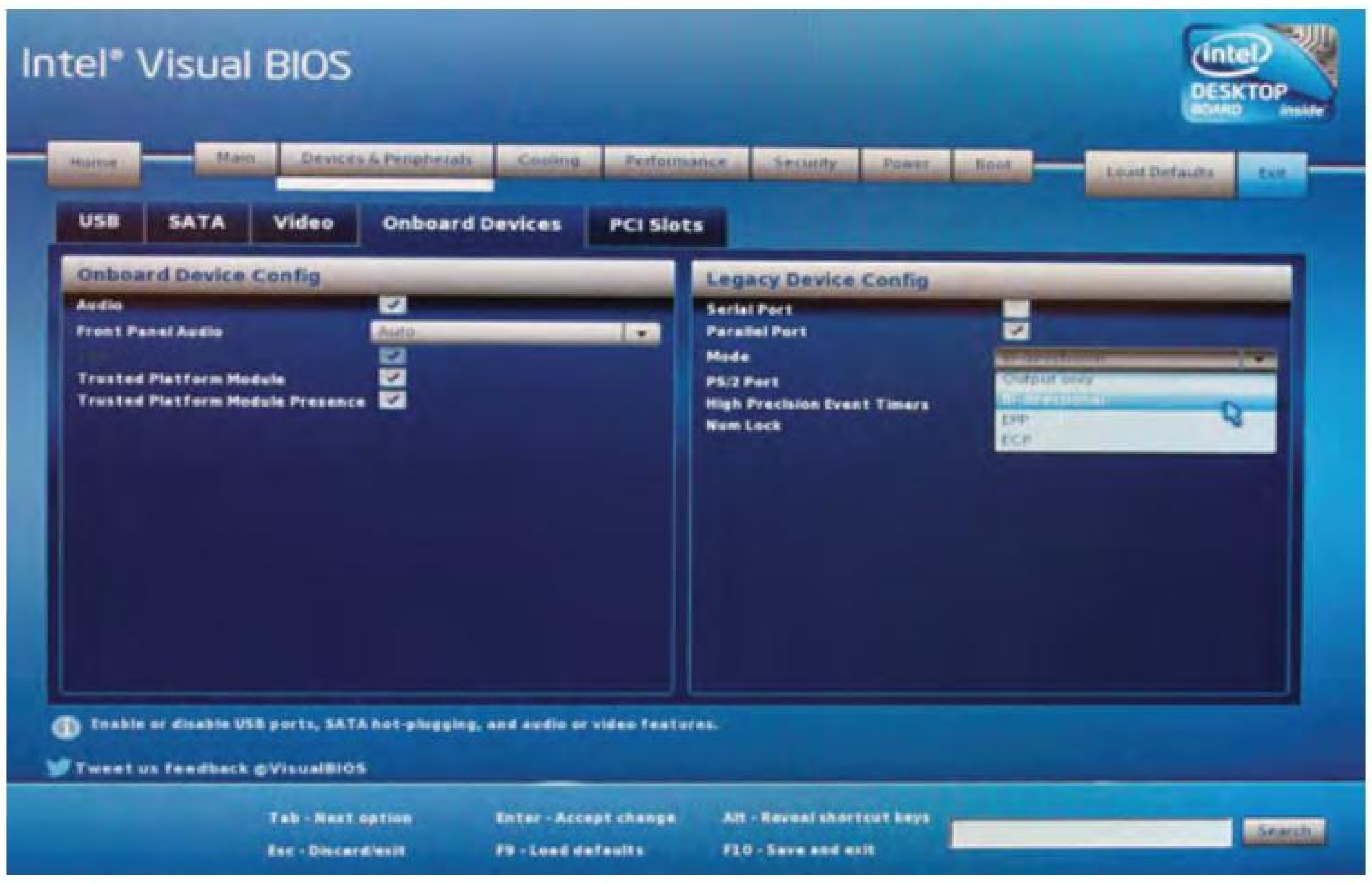
The method used to enter the Setup program depends on the particular make and model of PC you are using. In most cases an onscreen message appears during the initial testing phase after switch-on, indicating which key must be pressed in order to go into the built-in Setup program. This is typically the Esc, Del, F2 or F10 key. My PC was something less than helpful, and it only produced the Intel logo at start-up. However, a search of the Internet revealed that the F2 key was the one to use, and the Setup program duly appeared.

Once into the Setup program it is first a matter of finding the section that provides control over the built-in ports, and this will usually be called something like 'Integrated Peripherals' or 'Onboard Devices'. In this example (Fig.1), it was the 'Legacy Device Config' subsection of the 'Onboard Devices' section that was required. Ticking a checkbox activated the port, and a drop-down menu was then used to select the required mode of operation.

The 'Output Only' mode is the best choice if the data lines of the printer port will only be used as outputs. This mode avoids the possibility of accidentally setting the data lines as inputs. However, when experimenting with interfacing to the printer port it is likely that the data lines will be used as inputs at some stage, and the 'Bidirectional' mode is then required. The bidirectional mode is sometimes called the SPP (Standard Parallel Port) mode. Other modes, such as ECP and EPP support protocols for high speed data transfers, but are not needed when experimenting with simple computer interfacing.

Properly addressed

To directly control a printer port, its address range in the input/output map must be known. At one time it was often possible to select one of the standard address ranges via the BIOS Setup program, but this facility is not usually available with modern PCs. The address range will probably be fixed in the hexadecimal range 378 to 37F, but it can be from 278 to 27F, or 3BC to 3BF. This can be checked



Onboard Device Config

Audio ☑

Front Panel Audio Auto

☑

Trusted Platform Module ☑

Trusted Platform Module Presence ☑

Legacy Device Config

Serial Port ☐

Parallel Port ☑

Mode

PS/2 Port

High Precision Event Timers

Num Lock

Output only

Bi-directional

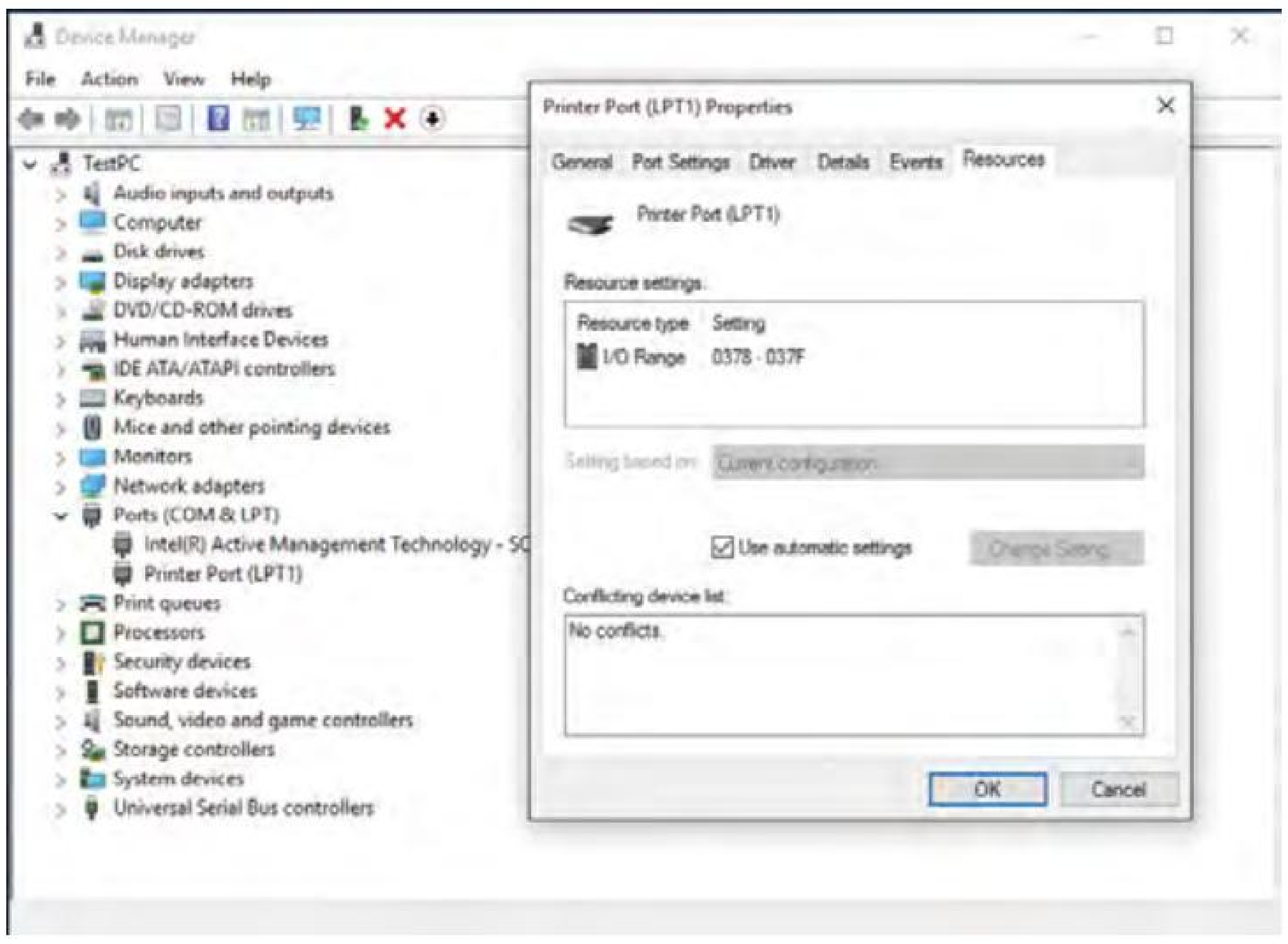
EPP

ECP

Enable or disable USB ports, SATA hot-plugging, and audio or video features.

Tweet us feedback @VisualBIOS

Fig.1. A built-in printer port usually has to be switched on via the BIOS Setup program before it can be used. The required operating mode can also be set here


Device Manager
File
Action
View
Help
TestPC
Audio inputs and outputs
Computer
Disk drives
Display adapters
DVD/CD-ROM drives
Human Interface Devices
IDE ATA/ATAPI controllers
Keyboards
Mice and other pointing devices
Monitors
Network adapters
Ports (COM & LPT)
Intel(R) Active Management Technology - SC
Printer Port (LPT1)
Print queues
Processors
Security devices
Software devices
Sound, video and game controllers
Storage controllers
System devices
Universal Serial Bus controllers
Printer Port (LPT1) Properties
General
Port Settings
Driver
Details
Events
Resources
Change Setting
OK
Cancel

Printer Port (LPT1)

Resource settings:

Resource type	Setting
I/O Range	0378 - 037F

Setting based on: Current configuration

☑ Use automatic settings

Conflicting device list:

No conflicts.

Fig.2. Device Manager can be used to determine the address range of a printer port. In this case, the standard range of 378 to 37F (hexadecimal) is used

using the Windows Device Manager. The easy way to run this using Windows 10 is to right click the Start button and select Device Manager from the pop-up menu.

Once into Device Manager, expand the Ports (Com and LPT) section and double-click the 'Printer Port (LPT1)' entry. This will launch the properties window for the printer port, and its address range will be shown under the 'Resources' tab, as in Fig.2. In this case, the port does have the usual 378 to 37F address range. It is only the three lowest addresses (378 to 37A) that are of interest here. It is worth taking a look at the Port Settings section of the printer port's Properties window (Fig.3). Make sure that the Plug N Play facility and interrupts are both disabled. This should ensure that any add-ons left connected to the printer port do not interfere with the normal operation of the PC when it is being used normally under Windows.

Reading the register

The base address is used to access the data lines, whether reading them or writing data to them. These lines are normally used to send or receive bytes of data, and it is just a matter of reading bytes from and writing bytes to the port. This is unlike the Raspberry Pi, where read and write operations work on a bit-by-bit basis, and some mathematics is involved in order to provide byte-size operations. On the other hand, with PC computing languages such as GW-BASIC and QBASIC there is no facility for reading or writing operations that involve single lines, which obviously complicates matters if the data lines need to be used as a set of individual inputs or outputs.

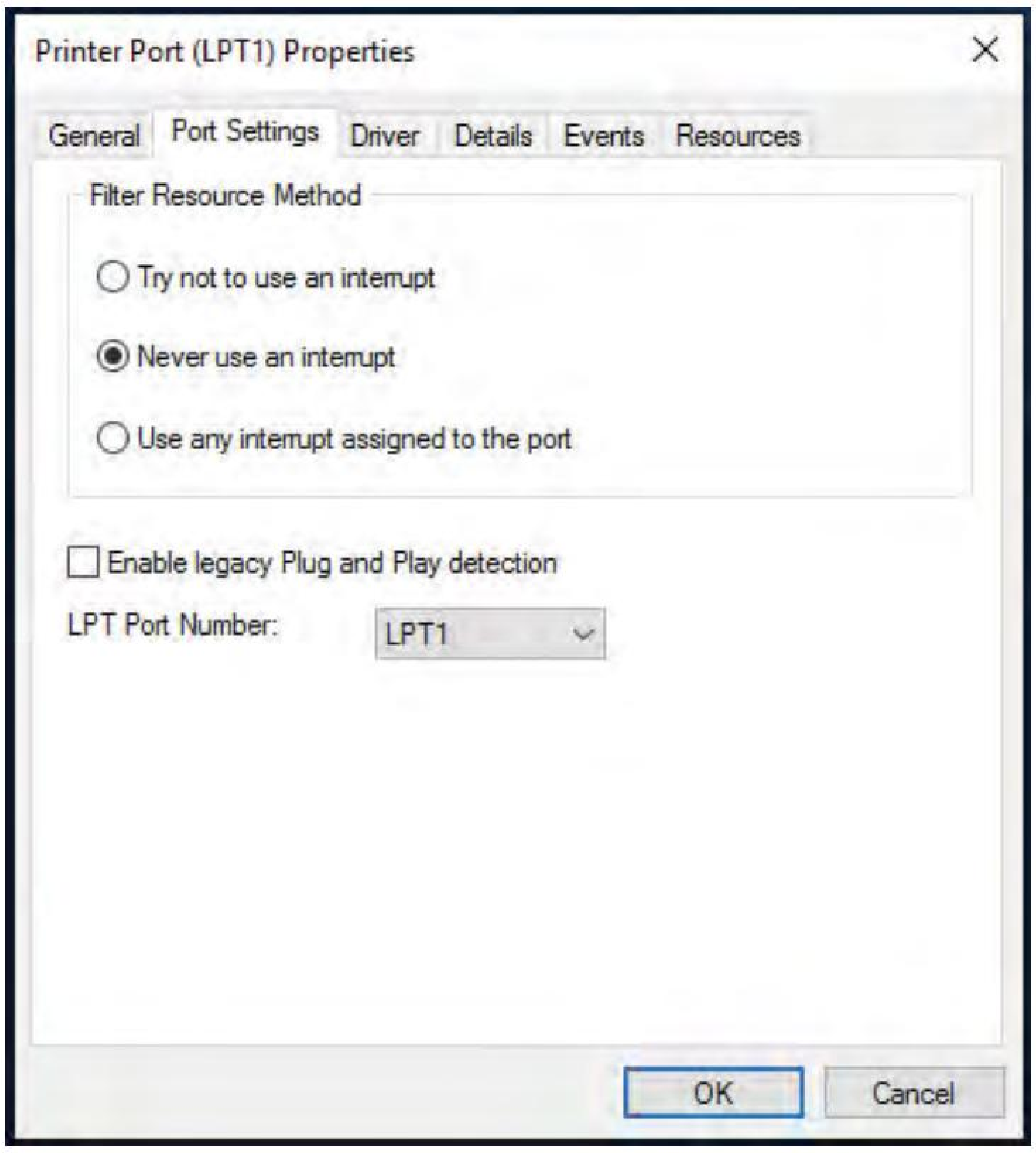
The register above the base address at 379 is a read-only status register. It is a status register in the sense that it was designed to read information about the state of the printer connected to the port, and it is really an input port that enables five input lines to be read. These are bits 3 to 7, as detailed in Table 1.

Table 1

Bit	Function	Inverted	Pin
3	Error	Yes	15
4	Select In	No	13
5	Paper Empty	No	12
6	Acknowledge	Yes	10
7	Busy	No	11

There is no facility for reading individual lines, but a single line can be read by using the bitwise XOR function and a suitable masking value. For example, the Error input at bit 3 contributes 8 to the returned value if it is set high, and it can therefore be read using a masking value of 8. In GW BASIC it would be read using a program line such as this:

```
X = INP(&H379) XOR 8
```


Printer Port (LPT1) Properties
General
Port Settings
Driver
Details
Events
Resources
OK
Cancel

Filter Resource Method

○ Try not to use an interrupt

● Never use an interrupt

○ Use any interrupt assigned to the port

☐ Enable legacy Plug and Play detection

LPT Port Number: LPT1

Fig.3. It is advisable to ensure that the Plug N Play facility and interrupts are both disabled. This can help avoid problems if a printer port add-on is left connected when the computer runs under Windows

The same method can be used to read individual lines of the 8-bit port when it is set as an input type. It should be borne in mind that the Acknowledge line at bit 6 (pin 10), and the Error line at bit 3 (pin 15) all have built-in inverters. This is not really a problem, but any software that reads these inputs must be designed to take the inversions into account.

In control

There is a control register at hexadecimal address 37A. It is a control register in the sense that it controls the printer, but it is also a conventional control register that is used to govern some aspects of the way in which the port operates. It is a write-only register, and only the six least-significant bits are used. Table 2 shows their functions.

Table 2

Bit	Function	Inverted	Pin
0	Strobe	Yes	1
1	Auto Feed	Yes	14
2	Initialise	Yes	16
3	Select Out	No	17
4	Enable IRQ	–	–
5	Port Direction Control	–	–

Bits 0 to 3 are handshake outputs, and all but the Select Out line at bit 3 (pin 17) have built-in inverters. Once again, this is not a problem, but any software that uses these lines must be designed to take the inversion into account. Bit 4 can be used to enable interrupts via the Acknowledge input, but this bit will normally be set to 0 so that the interrupt facility is disabled.

Bit 5 is of more importance in the current context, and it is used to set the direction of the 8-bit port. This assumes that bidirectional operation has been set in the BIOS Setup program. If not, the 8-bit port will operate as an output, and the state of bit 5 will be irrelevant. The port will default to the output mode if bidirectional operation has been selected, and writing a 1 to bit 5 of the control register will set it to the input mode. In other words, writing a value of 32 to hexadecimal output address 37A will set the input mode, and writing a value of 0 to this address will return the port to the output mode. There is no facility for writing values

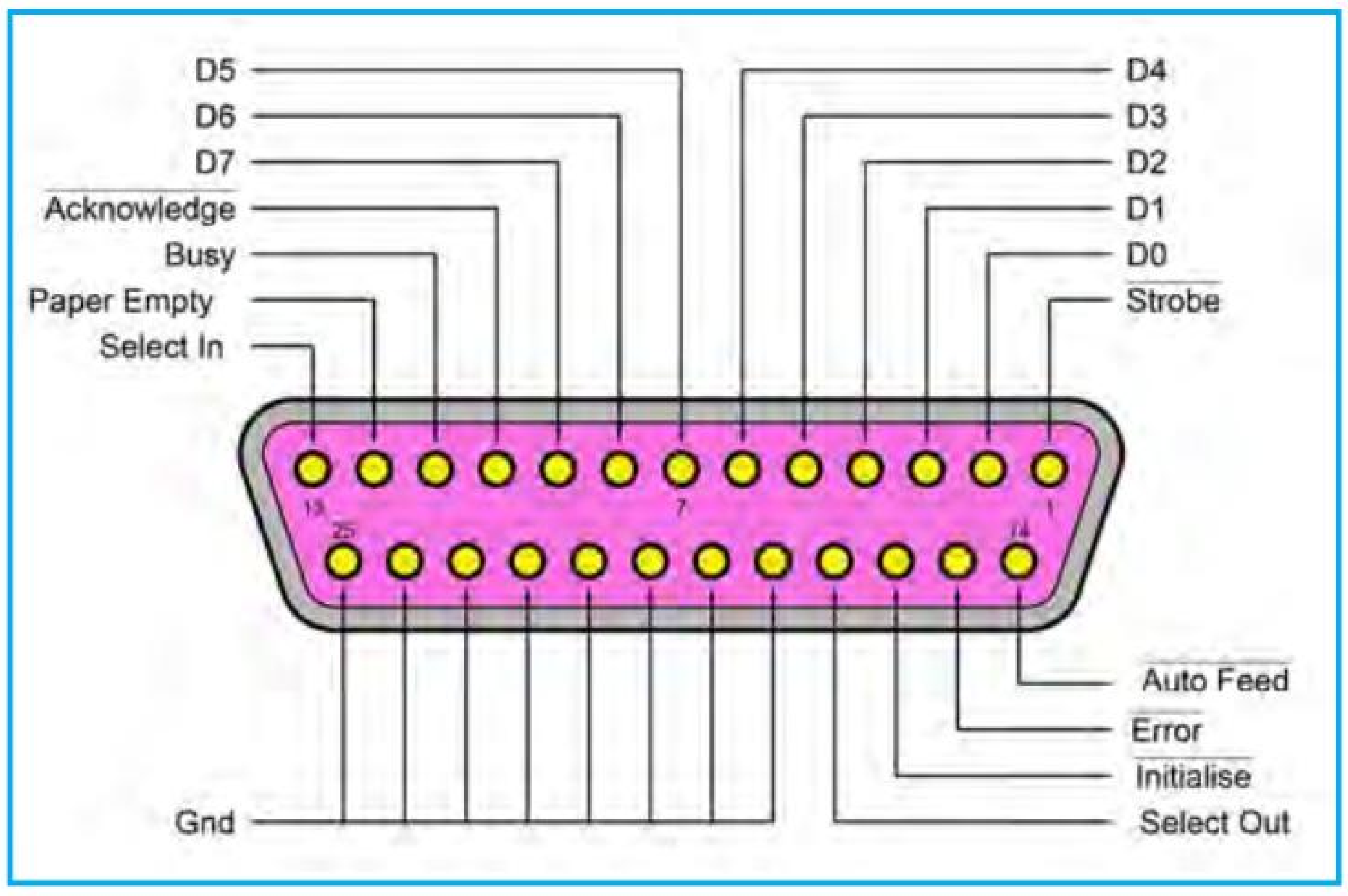


Fig.4. Connection details for a standard PC printer port. The connector is a 25-way female D type

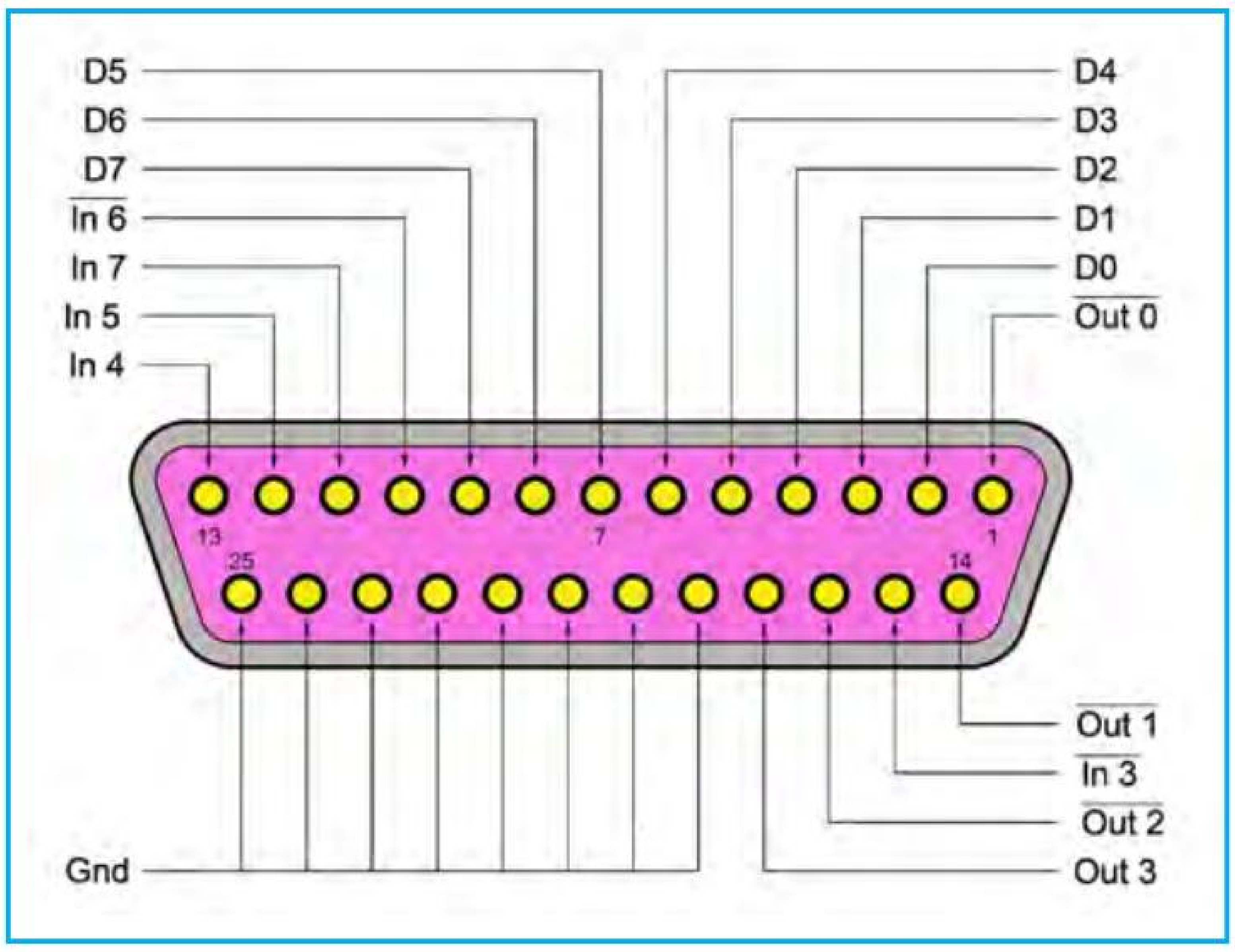


Fig.5. In the current context it is best to ignore the original functions of the handshake lines. Instead, think of them in terms of their direction and bit numbers in the Status and Control registers!

to individual bits of the Control register, and the software must therefore be carefully designed so that when one bit is altered, the other bits are left unchanged.

Making connections

Fig.4 shows connection details for a PC printer port, which uses a female 25-way D-type connector. Add-ons are normally connected to the port via a 25-way male D connector and a ribbon cable. When using the port for general interfacing it is probably best to ignore the intended functions of the handshake lines, and think of them in terms of their direction and bit numbers in the Status and Control registers. Fig.5, repeated from the previous *Interface* article, provides this easier way of looking at things.

There are numerous ground (earth) pins on the parallel port, and the general idea is to make connections to the port via a ribbon cable that has alternate ground and signal lines. The ground wires act as screens that minimise cross coupling of signals due to the capacitance in the cable. Even so, for fast data transfers the maximum usable cable length is only about two metres. Of course, for simple applications where (say) a few lights or relays are being controlled, and high-speed operation is not required, cross coupling is unlikely to be an issue. Relatively long cables of practically any type can then be used.

It is perhaps a shame that it is necessary to revert to old operating systems in order to get a suitably equipped PC to provide simple interfacing capabilities, but it does provide a way of using some modern PCs as viable alternatives to a Raspberry Pi for this type of thing. On the plus side, modern PCs have clock frequencies that are nearly a thousand times higher than those of the original PCs. Notoriously slow interpreted BASIC languages will actually operate reasonably fast on a modern PC.

HP 34401A Digital
Multimeter 6 ½ Digit

HP 54600B Oscilloscope Analogue/Digital
Dual Trace 100MHZ

LAMBDA GENESYS	PSU GEN100-15 100V 15A Boxed As New	£325
LAMBDA GENESYS	PSU GEN50-30 50V 30A	£325
HP34401A	Digital Multimeter 6.5 digit	£275-£325
HP33120A	Function Generator 100 microHZ-15MHZ	£260-£300
HP53131A	Universal Counter 3GHZ Boxed unused	£500
HP53131A	Universal Counter 225MHZ	£350
HP54600B	Digital Oscilloscope 100MHZ 20MS/S	from £75
IFR 2025	Signal Generator 9kHz - 2.51GHZ Opt 04/11	£900
Marconi 2955B	Radio Communications Test Set	£800
R&S APN62	Syn Function Generator 1HZ-260KHZ	£195
Fluke/Philips PM3092	Oscilloscope 2+2 Channel 200MHZ Delay etc	£250
HP3325A	Synthesised Function Generator	£195
HP3561A	Dynamic Signal Analyser	£650
HP6032A	PSU 0-60V 0-50A 1000W	£750
HP6622A	PSU 0-20V 4A Twice or 0-50V 2A Twice	£350
HP6624A	PSU 4 Outputs	£350
HP6632B	PSU 0-20V 0-5A	£195
HP6644A	PSU 0-60V 3.5A	£400
HP6654A	PSU 0-60V 0-9A	£500
HP8341A	Synthesised Sweep Generator 10MHZ-20GHZ	£2,000
HP83731A	Synthesised Signal Generator 1-20GHZ	£1,800
HP8484A	Power Sensor 0.01-18GHZ 3nW-10uW	£75
HP8560A	Spectrum Analyser Synthesised 50HZ - 2.9GHZ	£1,250
HP8560E	Spectrum Analyser Synthesised 30HZ - 2.9GHZ	£1,750
HP8563A	Spectrum Analyser Synthesised 9KHZ-22GHZ	£2,250
HP8566B	Spectrum Analsyer 100HZ-22GHZ	£1,200
HP8662A	RF Generator 10KHZ - 1280MHZ	£750
Marconi 2022E	Synthesised AM/FM Signal Generator 10KHZ-1.01GHZ	£325
Marconi 2024	Synthesised Signal Generator 9KHZ-2.4GHZ	£800
Marconi 2030	Synthesised Signal Generator 10KHZ-1.35GHZ	£750
Marconi 2305	Modulation Meter	£250
Marconi 2440	Counter 20GHZ	£295
Marconi 2945	Communications Test Set Various Options	£2,500
Marconi 2955	Radio Communications Test Set	£595
Marconi 2955A	Radio Communications Test Set	£725
Marconi 6200	Microwave Test Set	£1,500
Marconi 6200A	Microwave Test Set 10MHZ-20GHZ	£1,950
Marconi 6200B	Microwave Test Set	£2,300
Marconi 6960B with	6910 Power Meter	£295

MARCONI 2955B Radio
Communications Test Set

FLUKE/PHILIPS PM3092 Oscilloscope
2+2 Channel 200MHZ Delay TB, Autoset etc

Tektronix TDS3012	Oscilloscope 2 Channel 100MHZ 1.25GS/S	£450
Tektronix 2430A	Oscilloscope Dual Trace 150MHZ 100MS/S	£350
Tektronix 2465B	Oscilloscope 4 Channel 400MHZ	£600
Cirrus CL254	Sound Level Meter with Calibrator	£40
Farnell AP60/50	PSU 0-60V 0-50A 1KW Switch Mode	£195
Farnell H60/50	PSU 0-60V 0-50A	£500
Farnell B30/10	PSU 30V 10A Variable No Meters	£45
Farnell B30/20	PSU 30V 20A Variable No Meters	£75
Farnell XA35/2T	PSU 0-35V 0-2A Twice Digital	£75
Farnell LF1	Sine/sq Oscillator 10HZ-1MHZ	£45
Racal 1991	Counter/Timer 160MHZ 9 Digit	£150
Racal 2101	Counter 20GHZ LED	£295
Racal 9300	True RMS Millivoltmeter 5HZ-20MHZ etc	£45
Racal 9300B	As 9300	£75
Black Star Orion	Colour Bar Generator RGB & Video	£30
Black Star 1325	Counter Timer 1.3GHZ	£60
Ferrograph RTS2	Test Set	£50
Fluke 97	Scopemeter 2 Channel 50MHZ 25MS/S	£75
Fluke 99B	Scopemeter 2 Channel 100MHZ 5GS/S	£125
Gigatronics 7100	Synthesised Signal Generator 10MHZ-20GHZ	£1,950
Panasonic VP7705A	Wow & Flutter Meter	£60
Panasonic VP8401B	TV Signal Generator Multi Outputs	£75
Pendulum CNT90	Timer Counter Analyser 20GHZ	£750
Seaward Nova	PAT Tester	£95
Solartron 7150	6 1/2 Digit DMM True RMS IEEE	£65
Solartron 7150 Plus	as 7150 plus Temp Measurement	£75
Solatron 7075	DMM 7 1/2 Digit	£60
Solatron 1253	Gain Phase Analyser 1mHZ-20KHZ	£600
Tasakago TM035-2	PSU 0-35V 0-2A 2 Meters	£30
Thurlby PL320QMD	PSU 0-30V 0-2A Twice	£160-£200
Thurlby TG210	Function Generator 0.002-2MHZ TTL etc Kenwood Badged	£65

STEWART OF READING
17A King Street, Mortimer, near Reading, RG7 3RS
Telephone: **0118 933 1111** Fax: **0118 9331275**
USED ELECTRONIC TEST EQUIPMENT
Check website **www.stewart-of-reading.co.uk**

CIRCUIT SURGERY

REGULAR CLINIC

BY IAN BELL

SMT ferrite beads

FREQUENT contributor ***741*** posted a question about simulating ferrite beads on *EPE's Chat Zone* forum. His question refers to the impedance-frequency characteristics of the BLM18KG300TN1 taken from the device's datasheet (see Fig.1).

'How do I best derive values for simulation from the curves usually supplied for ferrite beads?
I can look at X=2.Pi.f.L for 100MHz, and solve for L – but the graphs show L itself varying (not just L being swamped by parasitic capacitance).

The curves show:
X: Presumably inductive reactance
Z: Impedance
R: Even this varies...

So X rises at first, but reduces at higher frequencies. (Skin effect, then v small effective conduction cross-section --> saturation I wonder?)
R basically rises with f (until very high frequency is reached. Is it basically an LCR? – If yes, why no values shown? If no, it's pretty obscure.'

Ferrite beads are used to prevent unwanted high frequency noise being conveyed through a conductor from one part of a circuit to another. A typical example is to prevent high frequency noise from a switch-mode power supply from getting to an analogue circuit whose performance will be degraded by the noise. They are often used to isolate the noise generated by the switching activity of high-speed digital ICs in one part of a power supply network from other parts of the supply. Ferrite beads are also used to prevent high frequency signals from being conducted onto wires and cables which may then act as antennae, transmitting the signal and causing electromagnetic interference (EMI) elsewhere. In this context, ferrite beads may be required to enable equipment to comply with regulations concerning the level of EMI produced. Similarly, ferrite beads can be used to prevent EMI signals being picked up by equipment cables and thereby causing interference.

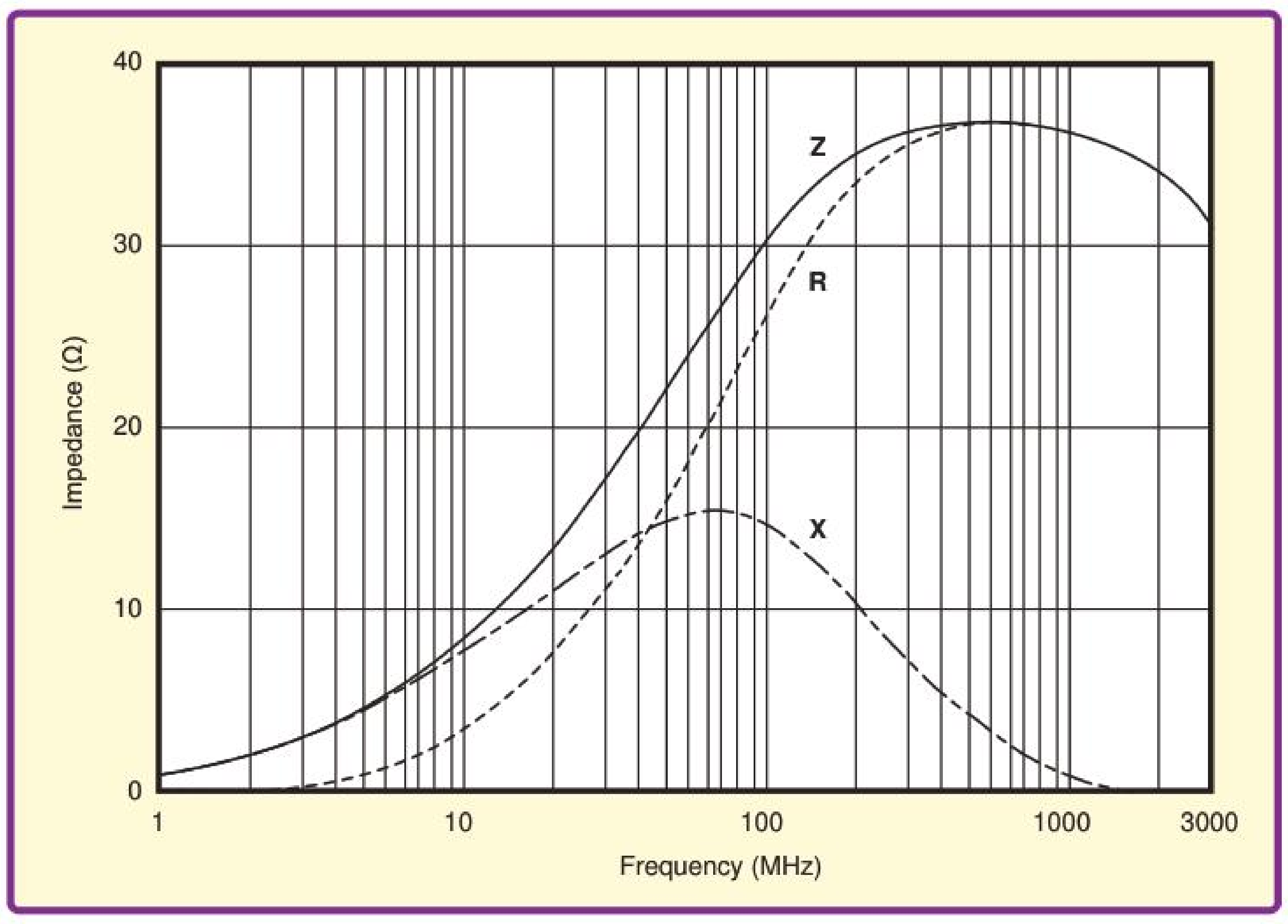
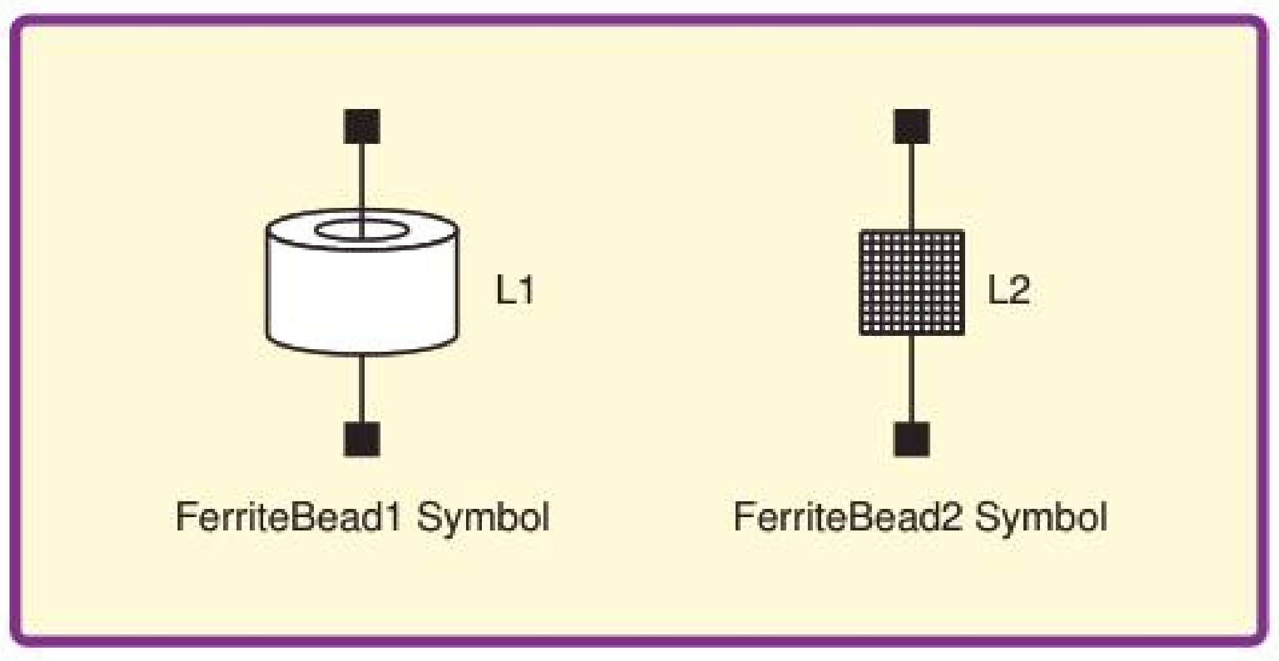


*Fig.1. Impedance-frequency characteristics of the BLM18 KG300TN1. From Murata data sheet (**www.murata.com**)*

A quick answer to ***741's*** question – as pointed out by ***istedman*** on the forum – is that LTSpice has a ferrite bead symbol, in fact it has two symbols (see Fig.2). So you can easily add one to your schematic, but that is only part of the story. The LTSpice ferrite bead symbols map to an inductor in the netlist, as indicated by the 'L' next to the symbol. This inductor is imperfect – it also contains resistance and capacitance; so in a way it is an LCR circuit as ***741*** suggested. (If you know parameters you can enter them via the LTSpice user interface, or you can use one of the built-in models of ferrite beads.) However, this is not the whole story, as indicated by Fig.1. A ferrite bead is not really a simple LCR circuit, and we will return to these issues in more detail after an overview of ferrite beads.

Fig.2. LTSpice ferrite bead symbols



Chip ferrite beads

The BLM18KG300TN1 mentioned by ***741*** is a surface mount (SMT) ferrite bead (also called a chip ferrite bead) from the BLM18K series of devices from the Japanese global electronics manufacturer Murata (see: **www.murata.com**). They form part of a range of noise suppression products marketed by Murata under the trademark EMIFIL (EMI FILters). SMT ferrite beads are of course available from other manufacturers, including Wurth Elektronik, TDK and Laird Technologies.

Although (PCB-mounted) ferrite beads are generally SMT devices, a few, particularly at higher current ratings are available in axial and radial leaded form. The SMT ferrite beads are available in the usual range of sizes for SMT chip devices, with larger devices generally having larger current ratings. The BLM18KG300TN1 mentioned by ***741*** is a 0603 size part (0.06 by 0.03 inches, or 1.6 by 0.8mm). If this device is unsuitable for your needs then there are plenty of others to choose from: at the time of writing, Farnell lists nearly 1700 ferrite bead devices.

Chip ferrite bead are inconspicuous looking components, indistinguishable from most surface mount resistors and capacitors in terms of their general appearance (see photo – Fig.3). Their key datasheet characteristics are impedance at 100MHz (and its tolerance, typically around 25%); DC resistance and DC current rating. Impedances at 100MHz range from approximately 50Ω to around 2.5kΩ; DC resistance typically covers the range 500μΩ to 2.5Ω; and current ratings range from about 50mA to about 10A. As might be expected, maximum operating currents must be derated at high operating temperatures (eg, above 85°C).

Fig.3. Typical surface-mount (chip) ferrite beads

The BLM18KG300TN1's spec is: 30Ω ±25% impedance at 100MHz (20°C); 5000mA maximum DC current (up to 85°C) and a maximum DC resistance of 0.010Ω.

The SMT chip is not the only form that ferrite beads take. The simplest geometry is just a ring of ferrite material, through which a wire or cable is either passed straight through, or wrapped around the ring a few times. This form of bead is common on computer leads, such as USB cables, and are also used on the wiring inside electronic equipment. Some chip ferrite beads have a similar structure with a wire simply passing through the bead of ferrite material, however, it is possible to achieve a higher impedance (in a given volume) by using a coil structure inside the chip (see Fig.4). This is done by building up layers of patterned conductors and ferrite sheet.

Complex curves

The curves in Fig.1 show that the ferrite bead behaves as either an inductor or a resistor depending on the frequency. At very high frequencies (mainly off of the graph in Fig.1) the bead also behaves like a capacitor. These different areas of operation are indicated in Fig.5. The inductive reactance is shown by the *X* curve and the resistance by the *R* curve. The changeover from inductive to resistive behaviour is taken to be the point where the *R* and *X* curves cross. The overall impedance of the bead, *Z*, is given by the complex number $Z = R + jX$.

If you are not familiar with 'complex numbers' don't worry, we are not going to use them throughout this article. However, we will provide a brief explanation now as it is an important aspect of Fig.1. In general, we need complex numbers when dealing with AC signals because we are concerned with both the *magnitude* of voltage and current and their *phase* relationship. For a resistor, the current and voltage are in phase. For an inductor (and a capacitor) the current is phase shifted by 90° with respect to the voltage (current *lags* voltage in an inductor, and current *leads* voltage in a capacitor).

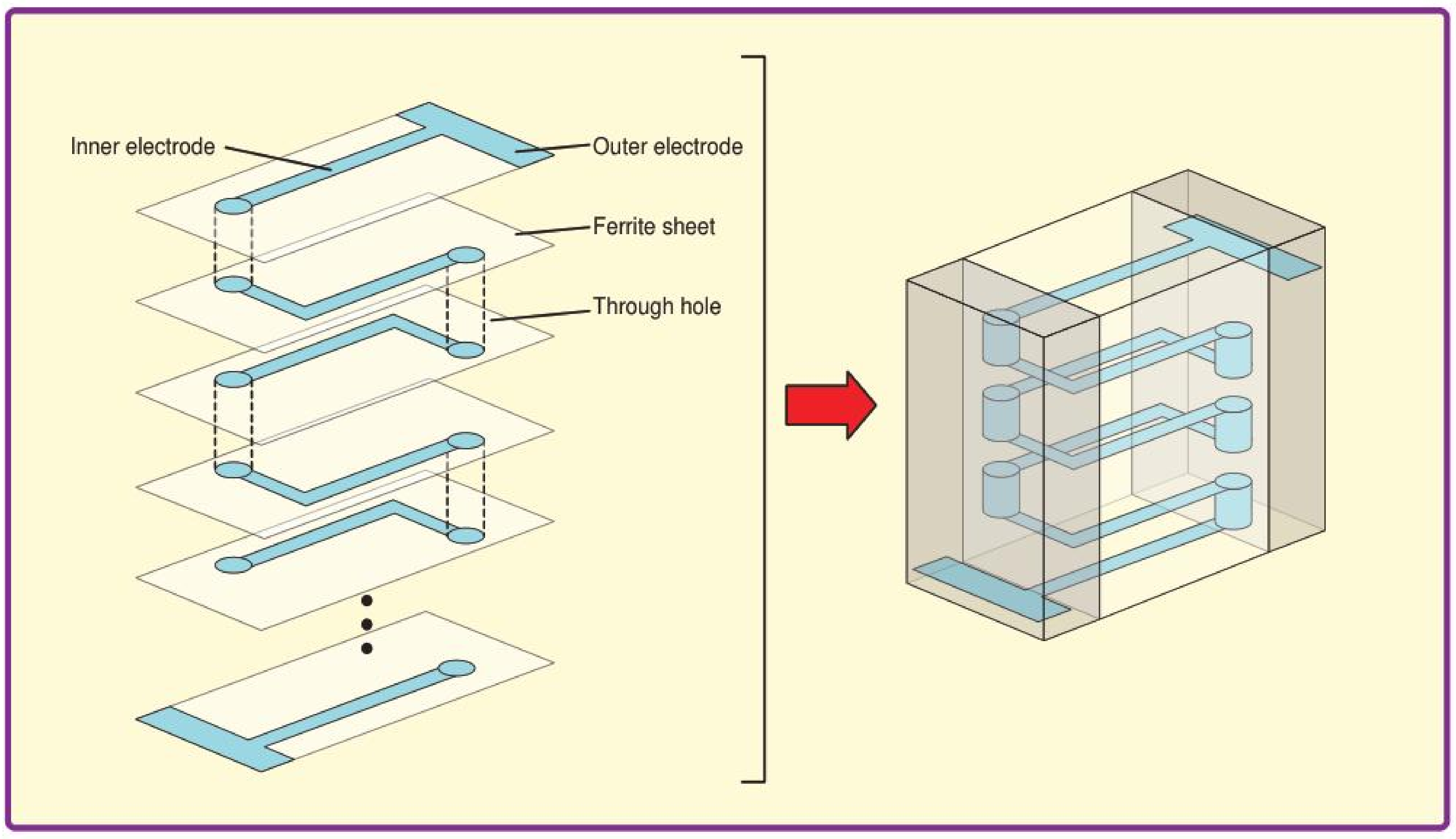


Fig.4. One possible internal structure of an SMT ferrite bead

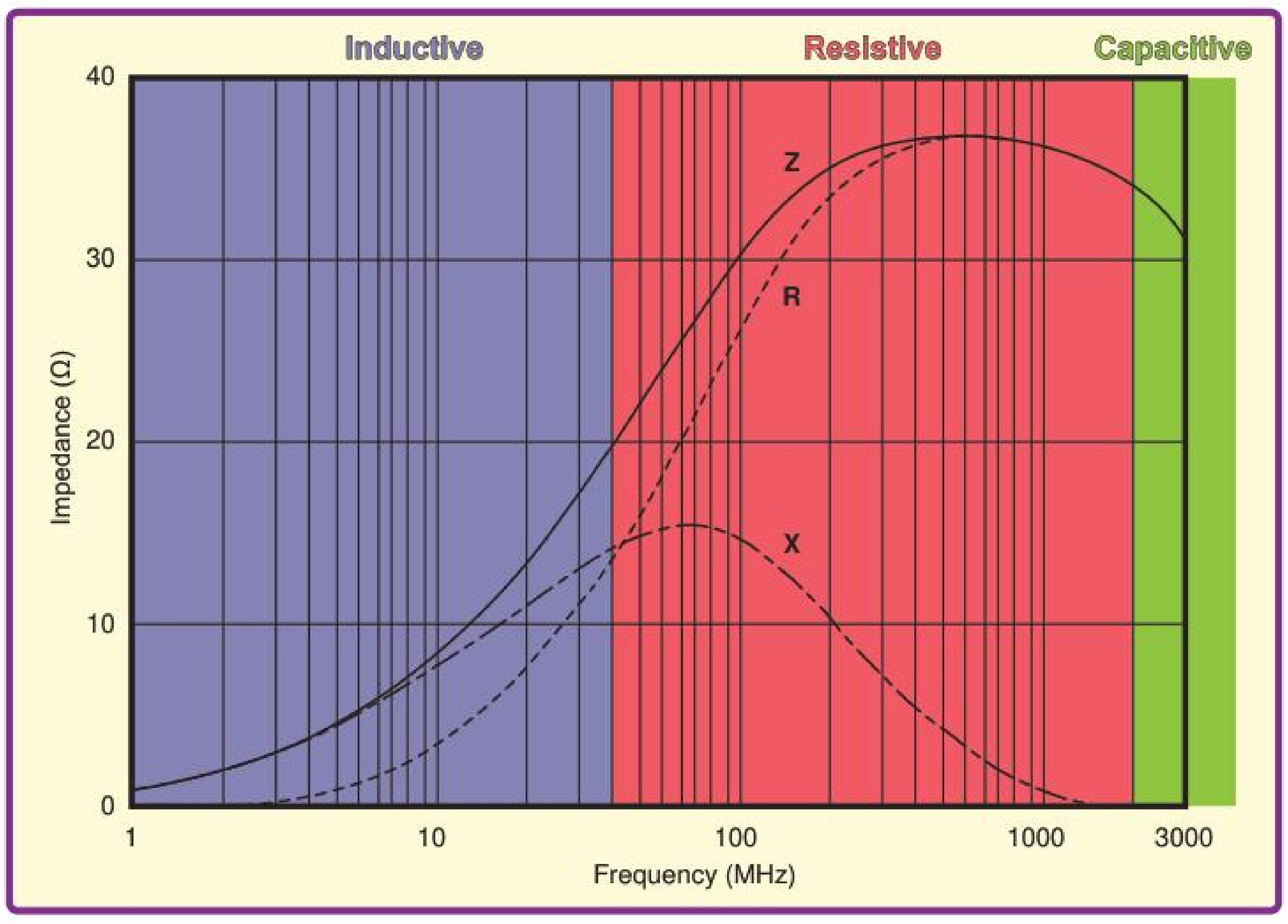


Fig.5. Here, Fig.1. has been redrawn to highlight the frequency-dependent inductive, resistive and capacitve behaviour of the ferrite bead. The capacitive region is mainly off the high frequency end of the graph

A single number (for 'the voltage' or 'the current') cannot encompass both the amplitude and phase shift. Complex numbers are two dimensional and therefore able to represent both amplitude and phase simultaneously. In the impedance equation *j* is the square root of minus one. The parts of the number multiplied by *j* are called 'imaginary' and the other part is 'real'. The real and imaginary parts are the two dimensions of the complex number. For a complex value $x + jy$ the magnitude and phase in ordinary numbers are given by:

Magnitude of $x+jy=\sqrt{x^2+y^2}$

Phase of $x+jy=\tan^{-1}(y/x)$

By the way, mathematicians use the symbol 'i' (not 'j') for the square root of minus one ($i = \sqrt{-1}$) – electronics engineers avoid this convention by using 'j' to prevent confusion with the use of 'i' as the symbol for current.

Losses and dissipation

The inductive reactance curve in Fig.1 may seem odd, because for an ideal inductor the reactance is given by $X_L = 2\pi fL$, so we might expect X_L to increase steadily with frequency. The reason X_L does not increase like this is because the bead inductance, *L*, decreases as frequency increases. Similarly, an ideal resistance has the same value at all frequencies, but the resistance of the bead increases with frequency and then levels off and decreases. These characteristics are related to the physics and magnetic behaviour of the material used in the beads. This brings us to the reason why ferrite beads are useful for blocking high frequency noise.

A key difference between resistors and inductors (and capacitors) is that resistors dissipate energy and inductors (and capacitors) store it. That is, when a current flows through a resistor electrical energy is converted to heat energy and lost from the circuit. When a current flows in an ideal inductor a magnetic field is created which stores energy. When the applied current stops, the field collapses returning all the energy to the circuit. For a real inductor the process of energy storage is not perfect and some energy is lost, for example by eddy currents flowing in the material of the inductor's core.

For ferrite beads these losses increase with the frequency of the applied signal, and at sufficiently high frequencies most of the energy of the applied signal is dissipated. This is exactly what you want if you want to

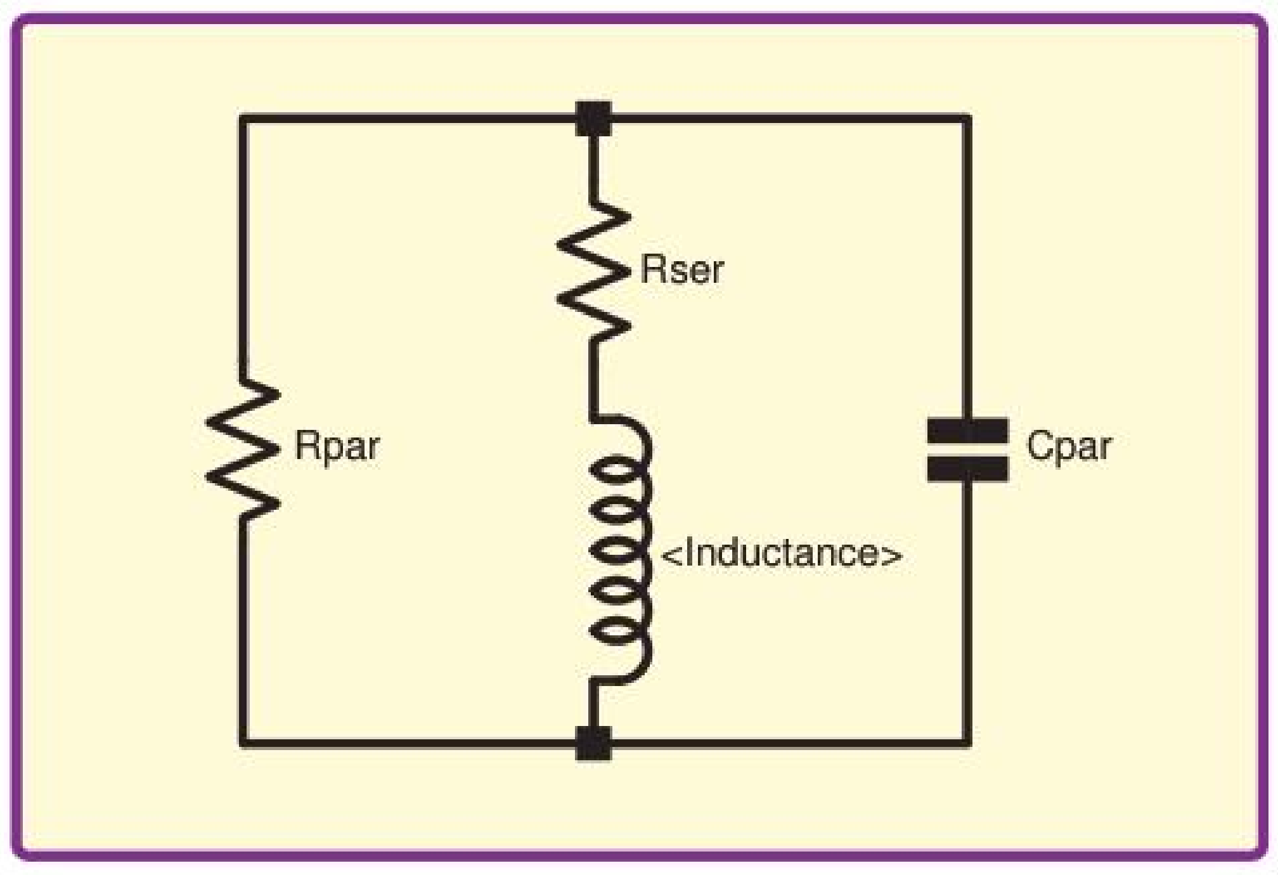
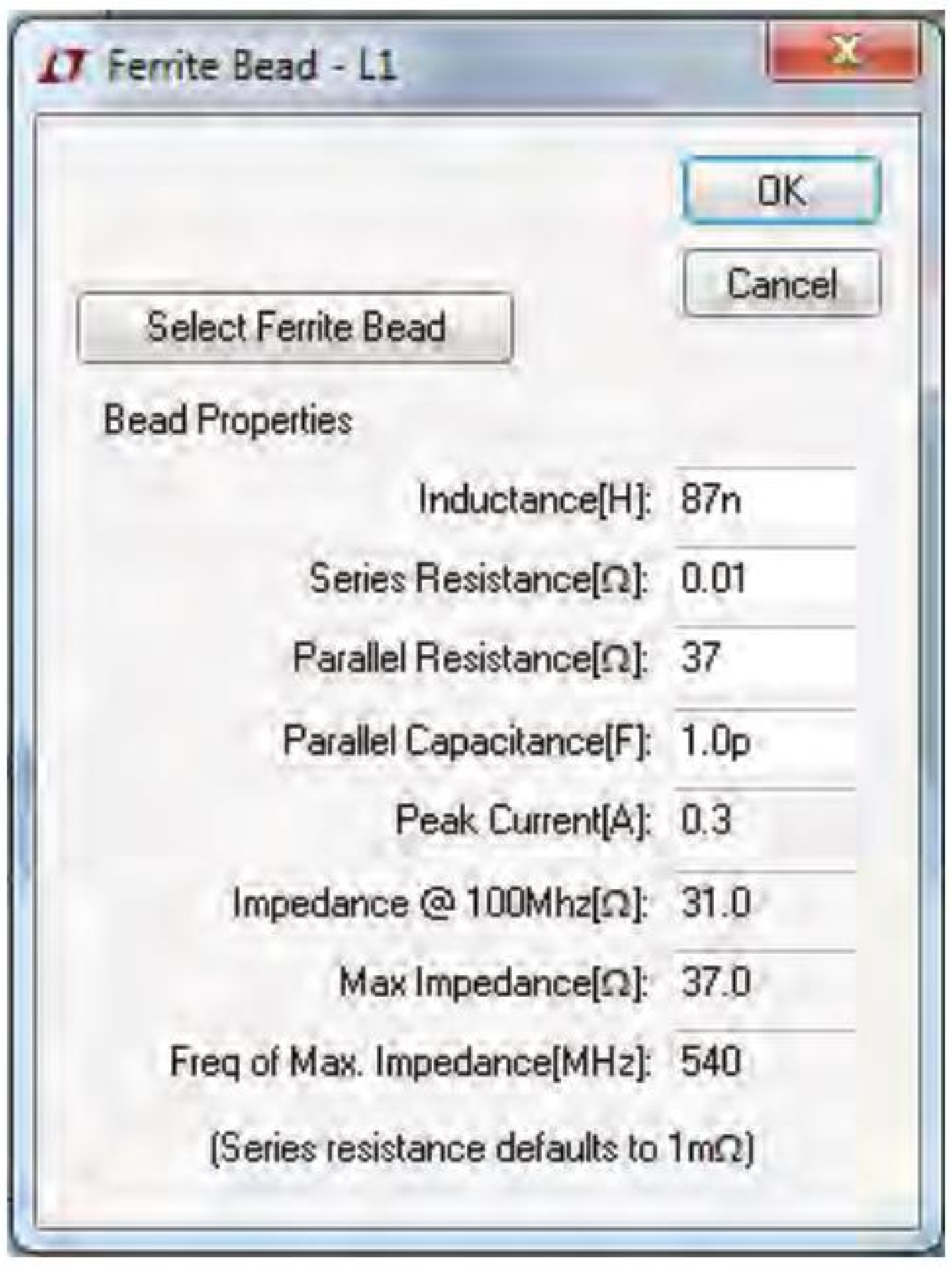


Fig.6. LTSpice inductor model with parasitics

get rid of noise. A pure inductor might have high impedance, but if the energy is not dissipated (as heat) it may still have a detrimental effect. It is resistive (dissipative) behaviour that is required at high frequencies, and this is exactly what the ferrite bead provides, as indicated by Fig.1. At very low frequencies (well below the range on Fig.1) and at DC, the beads have very low resistance, so they can be used in series with power lines without causing significant voltage drop at reasonable supply currents.



Bead Properties

Inductance[H]: 87n
Series Resistance[Ω]: 0.01
Parallel Resistance[Ω]: 37
Parallel Capacitance[F]: 1.0p
Peak Current[A]: 0.3
Impedance @ 100Mhz[Ω]: 31.0
Max Impedance[Ω]: 37.0
Freq of Max. Impedance[MHz]: 540
(Series resistance defaults to 1mΩ)

Fig.8. LTSpice ferrite bead properties dialog

LTSpice bead

The model of a non-ideal inductor used by LTSpice when you place a ferrite bed symbol on a schematic is shown in Fig.6. The model includes parasitic resistance (both series and parallel) and parallel capacitance. These 'parasitics' represent the fact that real components are never pure R, L or C. For example, an inductor will have some resistance because its wiring will not be a perfect conductor and will have some capacitance from end to end because of the packaging. The parasitics could be modelled by including them as drawn components on the schematic, but this is more work for the user and results in a less efficient simulation – internally LTSpice models the inductor parasitics together rather than as individual components.

The schematic in Fig.7 can be used to investigate the variation of ferrite bead impedance with frequency. We simply apply a voltage and perform a small-signal analysis. If we plot voltage divided by current from the simulation results we will get a graph of impedance variation. To set up the bead parameters, right click on the symbol. The dialog shown in Fig.8 will appear, allowing values for the inductance and parasitics to be set up.

The question arises of course as to how we choose the right values to enter, which is the crux of ***741's*** question. This is not immediately obvious, in particular there is no inductance specified on the datasheet. We can use the graph of Fig.1 to estimate a value. For example, the graph of X_L (inductive reactance) indicates am impedance due to the inductance of 11Ω at 20MHz. Using $X_L = 2\pi fL$ we can estimate $L = 11/(2 \times \pi \times 20\times10^6) = 87$nH. The series resistance can be set from the datasheet DC resistance of 0.010Ω. The parallel resistance can be set by looking at the largest value of impedance on the graph in Fig.1, which is about 37Ω.

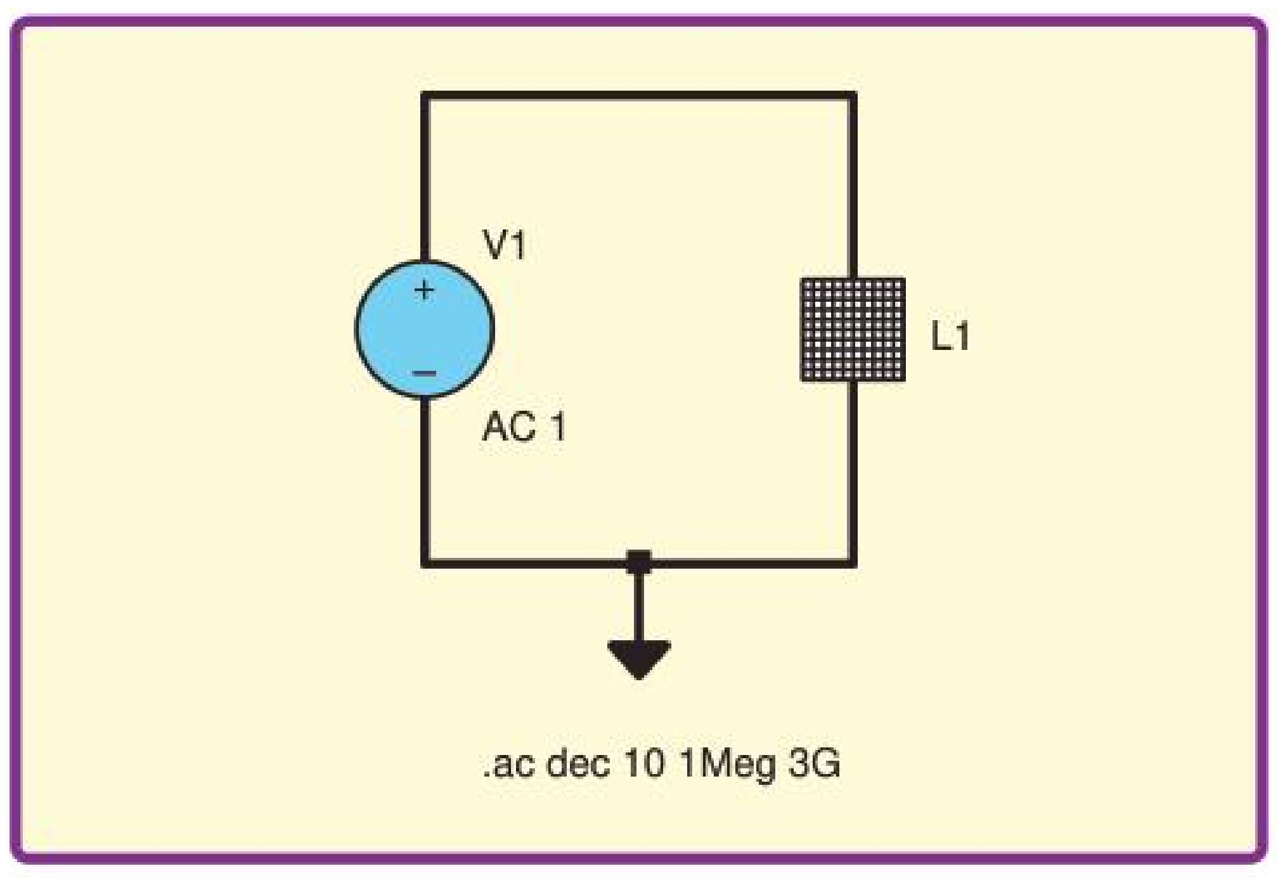


Fig.7. LTSpice circuit for ferrite bead impedance investigation

Guessing game

The capacitance is a bit more difficult to guess. Typical SMT chip passive packages have capacitances in the 0.5 to 1.5pF range, so we might expect something of this order. At the high frequency end of the curve in Fig.1, assuming the model in Fig.6, the total impedance will be due to the parallel combination of the capacitance and parallel resistance. If we assume the resistance is 37Ω and combined parallel impedance is about 30Ω we arrive at a capacitance of around 0.7pF using $X_C = 1/(2\pi fC)$. This can be tweaked experimentally, as can other parameters to try to match the curves, although how worthwhile such an exercise would be in a real design situation is open to question – there are better models available, as we will see.

If we netlist the circuit in Fig.7 after setting the parameters (View –> SPICE Netlist in the LTSpice menu) we get the following, confirming that the ferrite bead model uses a single inductor with parasitics from the ferrite bead dialog:

```
L1 N001 0 87n Ipk=0.3 Rser=0.01 Rpar=37 Cpar=1.0p
V1 N001 0 AC 1
.ac dec 10 1Meg 3G
.backanno
.end
```

Curve fit

The results from performing an AC analysis simulation are shown in Fig.9. The curve appears to be about the right shape, but if we superimpose it on the graph for Fig.1, as shown in Fig.10, we see that the match is not particularly good, principally at lower frequencies. Our curve coincides with the X curve at the 'calibration' point we used, and as previously mentioned we could try playing with the parameters to improve the match, but it might be a waste of time.

If we draw the equivalent circuit of the inductor and its parasitics directly in an LTSpice schematic, rather than using the recommended single-inductor model we can see the individual contributions of the components to the total impedance. A suitable schematic is shown in 11 – the bead is included for comparison purposes. The series resistance is placed in series with all three other components to provide a convenient point for measuring the total current in the drawn model. Its value is very low, so this will not make a significant difference at the frequencies of interest.

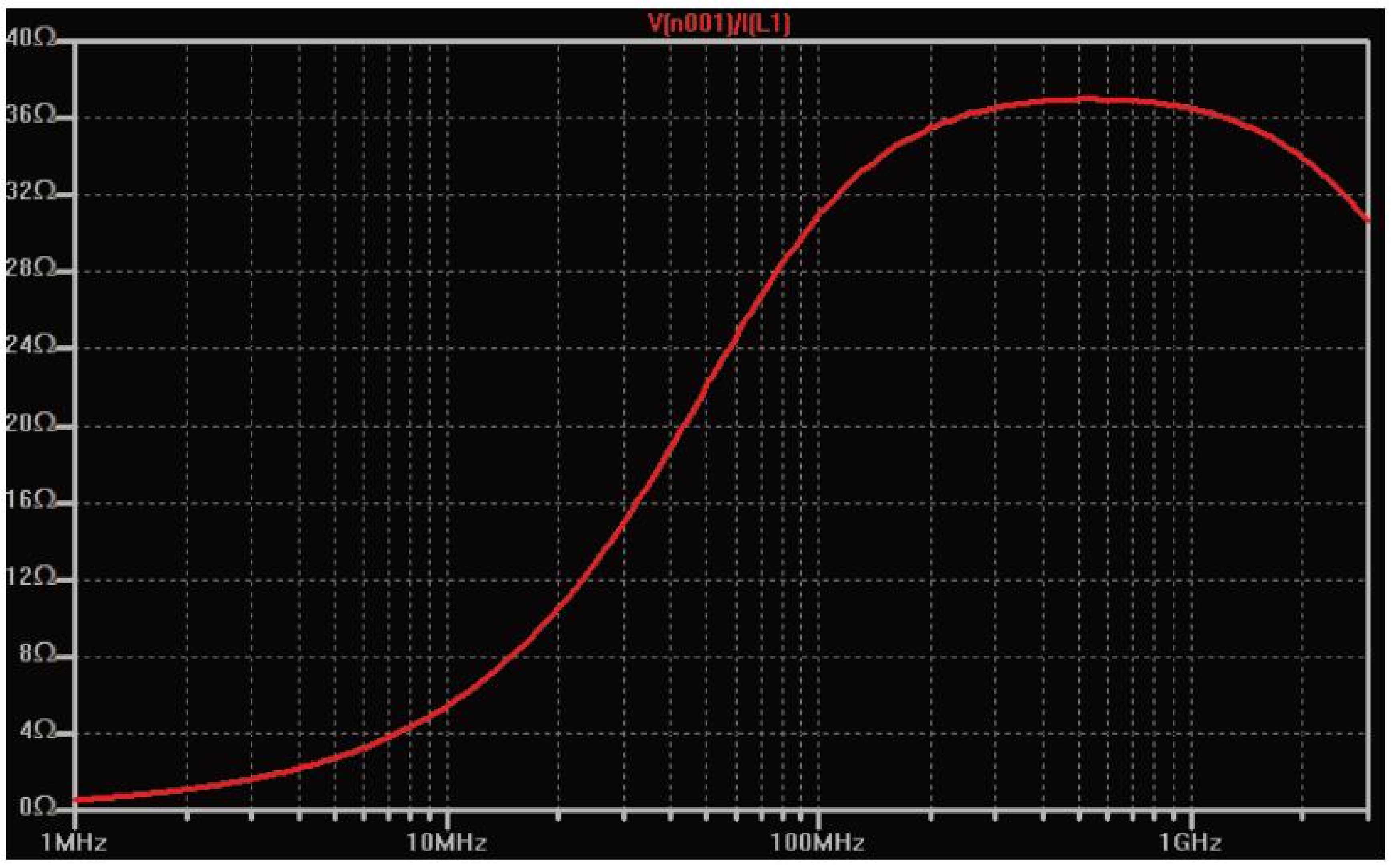


Fig.9. LTSpice simulation results for the circuit in Fig.7. Plot of bead impedance from 1Mz to 3GHz.

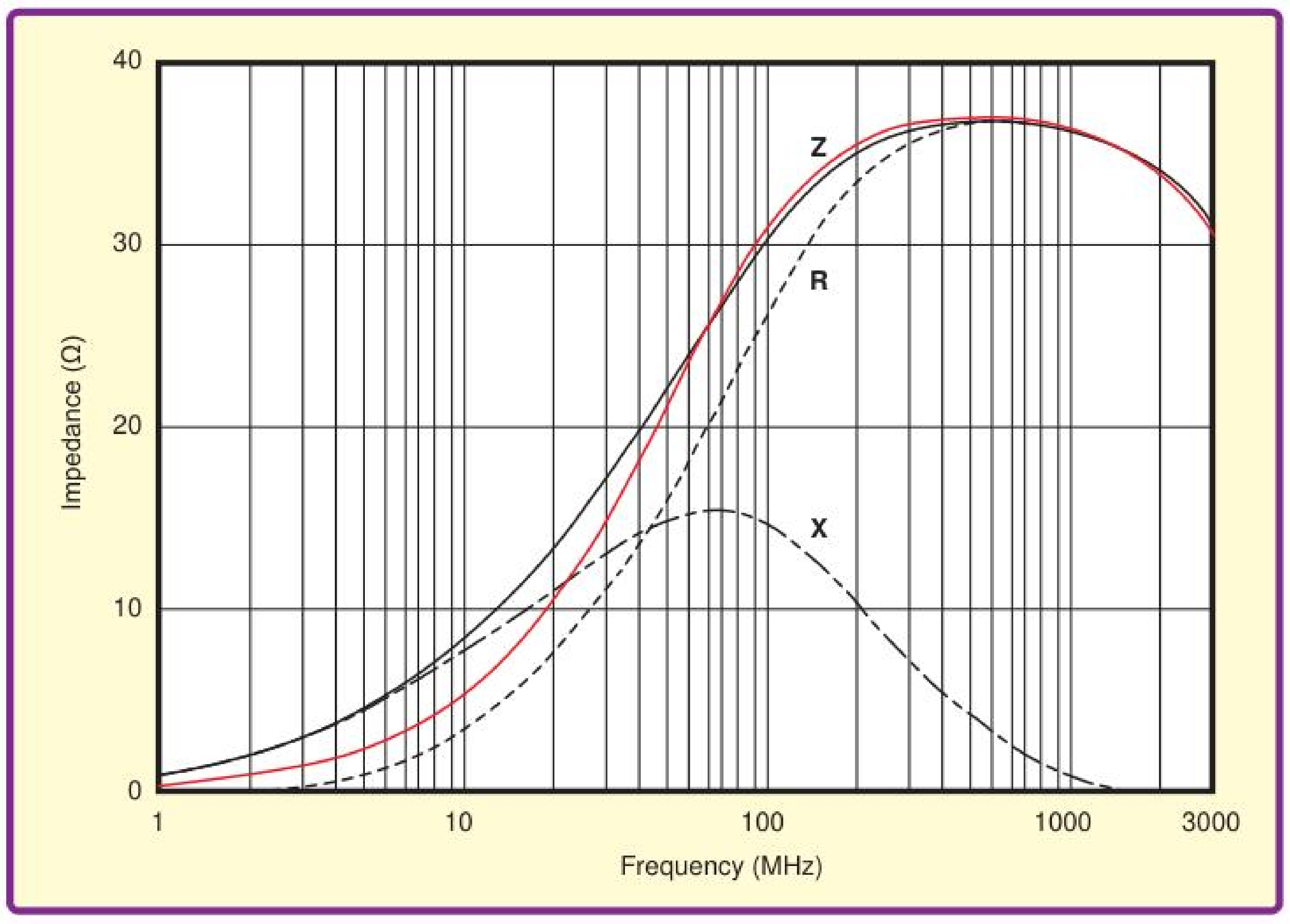


Fig.10. Comparison of the datahseet impedance-frequency characteristics of the BLM18KG300TN with the LTSpice ferrite bead using the parameters from Fig.8. The simulated curve is shown in red

The results are shown in Fig.12. We see that at low frequencies, below tens of MHz, the bead impedance is close to that of the inductor. In the medium range (100MHz to 1GHz) the resistor dominates and at high frequencies the capacitor takes over. Remember, the three components are in parallel, so it is the one with the lowest impedance at a given frequency which will have the dominant influence on the total current.

This model is not very representative of the true behaviour of a ferrite, whether we use the single inductor with parasitics, or the drawn schematic. The values of inductance and resistance in the models in Fig.7 and Fig.11 are constant and difficult to match to the real data because their effective values vary in a real ferrite bead. However, in very general terms the results in Fig.11 serve to illustrate how a component's behaviour can change with frequency between its inductive, resistive and capacitive properties.

SimSurfing

The difficulty of modelling ferrite beads means that manufactures often provide downloadable models for use in simulation. Murata provide an online software tool called 'SimSurfing', which simulates the characteristics of Murata products on their website and provides characteristic graph plotting, part selection and access to downloadable data and models. To use it, visit: **ds.murata.co.jp/software/simsurfing/en-us/**

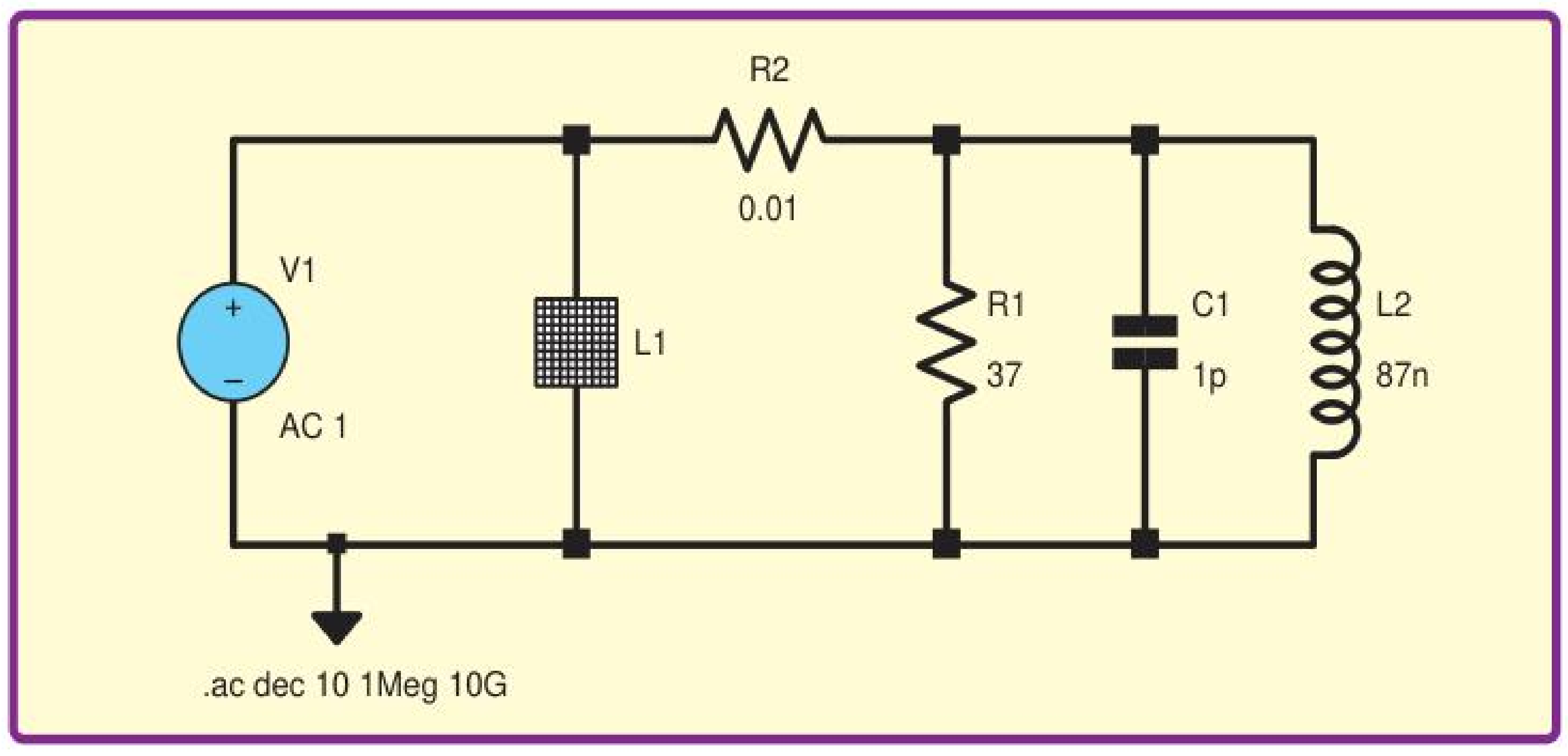

R2
0.01
V1
+
–
AC 1
L1
R1
37
C1
1p
L2
87n
.ac dec 10 1Meg 10G

Fig.11. LTSpice schematic for investigating contributions of the inductor parasitics

To find the data for the BLM18KG300TN1 click on 'EMI Suppression Filters' on the SimSurfing home page and then select the 'Ferrite Beads' tab. Type or paste a part number into the 'Part Number' Search box. The result will be similar to that shown in the screen shot in Fig.13. To obtain a SPICE model click on the 'Netlist' button. This will download a `.mod` file, which is a text file containing a SPICE sub-circuit model of the component (see Fig.14). A schematic of the model is shown in Fig.15.

The results of simulating the Murata model of the BLM18KG300TN1 are shown in Fig.16, again superimposed on the datasheet characteristics. We see that the fit to the impedance curve is much better than for the single-inductor model of the bead shown in Fig.10. The greater complexity of the model in Fig.15 provides more control over the shape of the impedance curve, allowing a better fit to be achieved.

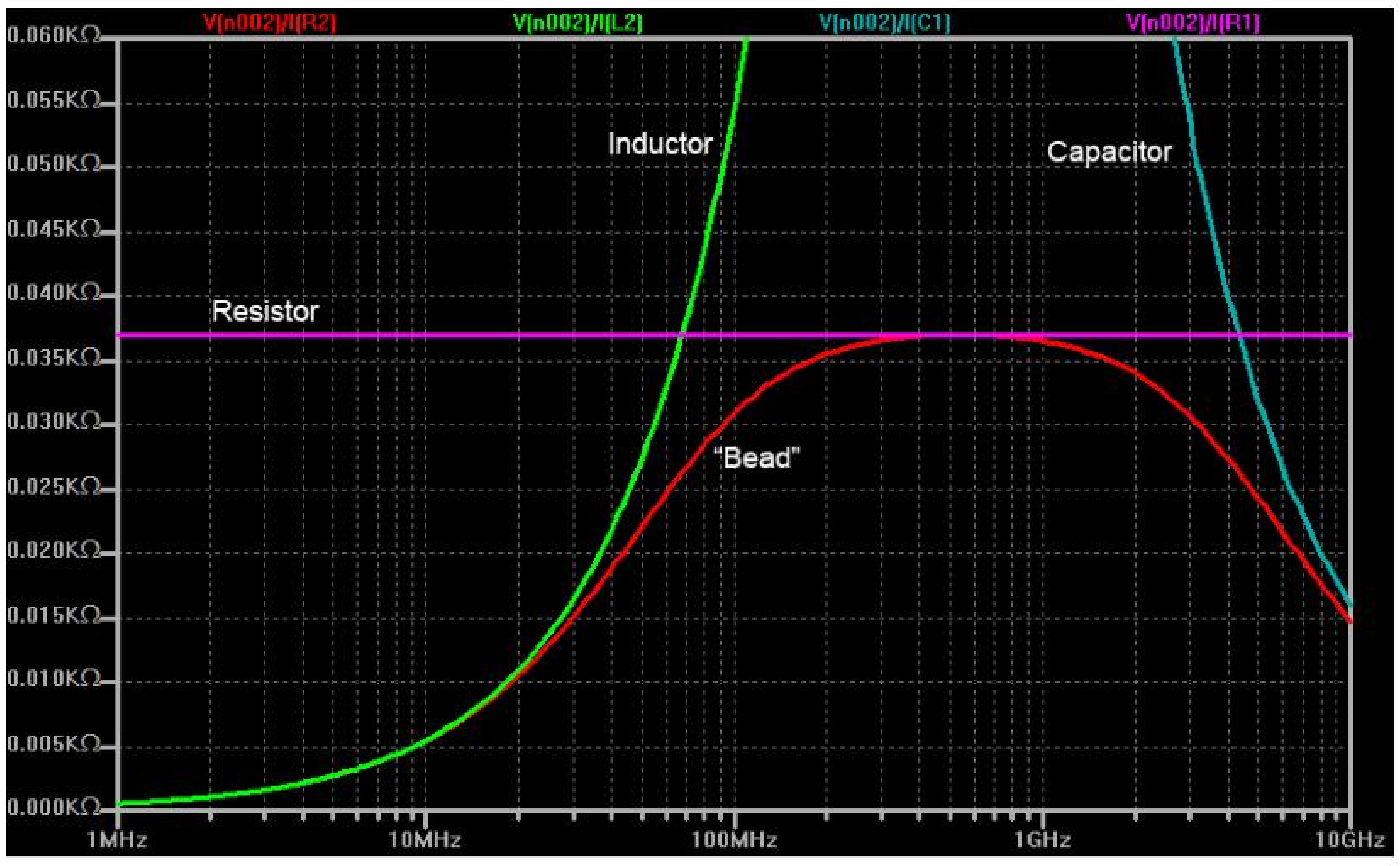
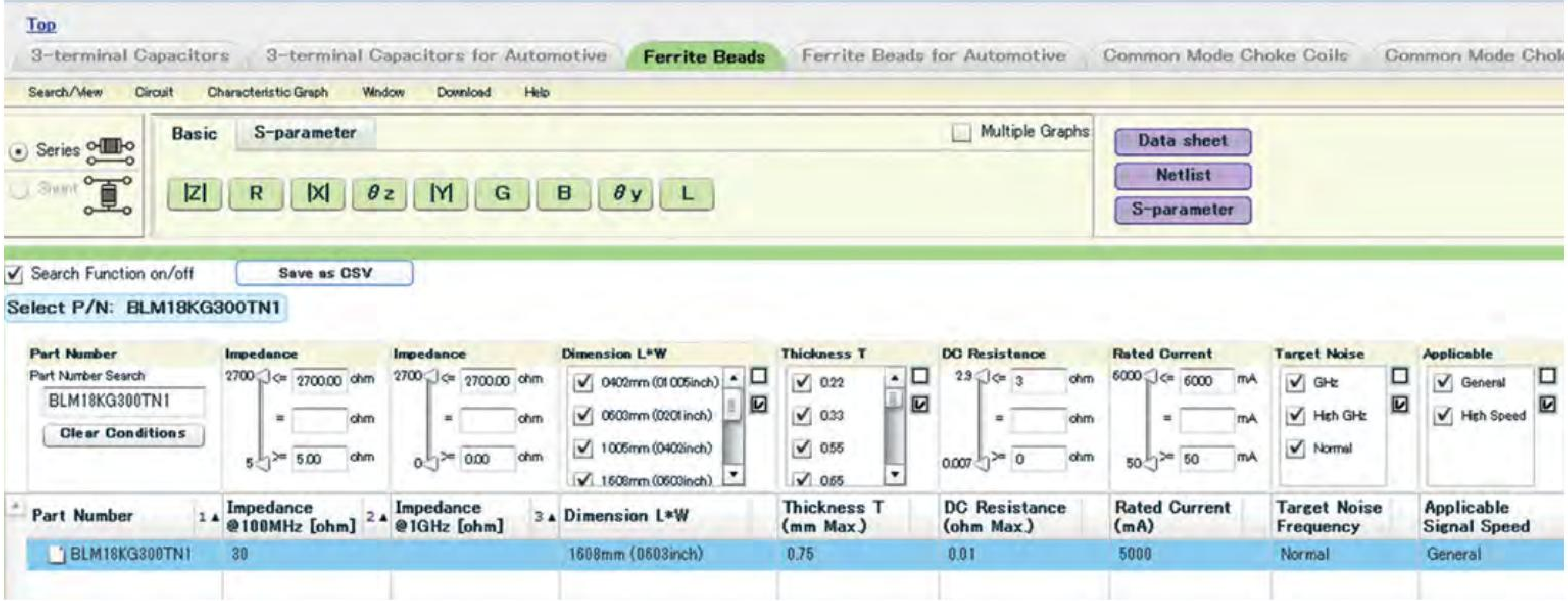


Fig.12. Results from simulation of circuit in Fig.11


Top
3-terminal Capacitors
3-terminal Capacitors for Automotive
Ferrite Beads
Ferrite Beads for Automotive
Common Mode Choke Coils
Common Mode Chok
Search/View
Circuit
Characteristic Graph
Window
Download
Help
● Series
○ Shunt
Basic
S-parameter
☐ Multiple Graphs
Data sheet
Netlist
S-parameter
|Z|
R
|X|
θz
|Y|
G
B
θy
L
Save as CSV
Clear Conditions

☑ Search Function on/off

Select P/N: BLM18KG300TN1

Part Number Search: BLM18KG300TN1

Impedance: 2700 <= 2700.00 ohm; = ohm; 5 >= 5.00 ohm

Impedance: 2700 <= 2700.00 ohm; = ohm; 0 >= 0.00 ohm

Dimension L*W: ☑ 0402mm (01005inch) ☑ 0603mm (0201inch) ☑ 1005mm (0402inch) ☑ 1608mm (0603inch)

Thickness T: ☑ 0.22 ☑ 0.33 ☑ 0.55 ☑ 0.65

DC Resistance: 2.9 <= 3 ohm; = ohm; 0.007 >= 0 ohm

Rated Current: 6000 <= 6000 mA; = mA; 50 >= 50 mA

Target Noise: ☑ GHz ☑ High GHz ☑ Normal

Applicable: ☑ General ☑ High Speed

Part Number	1 ▲ Impedance @100MHz [ohm]	2 ▲ Impedance @1GHz [ohm]	3 ▲ Dimension L*W	Thickness T (mm Max.)	DC Resistance (ohm Max.)	Rated Current (mA)	Target Noise Frequency	Applicable Signal Speed
BLM18KG300TN1	30		1608mm (0603inch)	0.75	0.01	5000	Normal	General

Fig.13. Screenshot from Murata's online SimSurfing software which provides data on its components. Here, information relating to the BLM18KG300TN1 is displayed

```
*-------------------------------------------------------
* SPICE Model generated by Murata Manufacturing Co., Ltd.
* Copyright(C) Murata Manufacturing Co., Ltd.
* MURATA P/N : BLM18KG300TN1
* Property : Z@100MHz = 30[ohm]
*-------------------------------------------------------
* Applicable Conditions:
*   Frequency Range = 1MHz - 3GHz
*   Temperature = 25 degC
*   DC Bias Current = 0 A
*   Small Signal Operation
*-------------------------------------------------------
.SUBCKT BLM18KG300TN1 port1 port2
R1 port1 1 8.186
L1 port1 1 9.425e-8
C1 port1 2 3.026e-12
R2 1 2 3.405e-1
L2 1 2 3.921e-9
R3 2 3 27.95
L3 2 3 5.944e-8
R4 3 port2 7.000e-3
.ENDS BLM18KG300TN1
*-------------------------------------------------------
```

Fig.14. Spice code from Murata's model of the BLM18KG300TN1

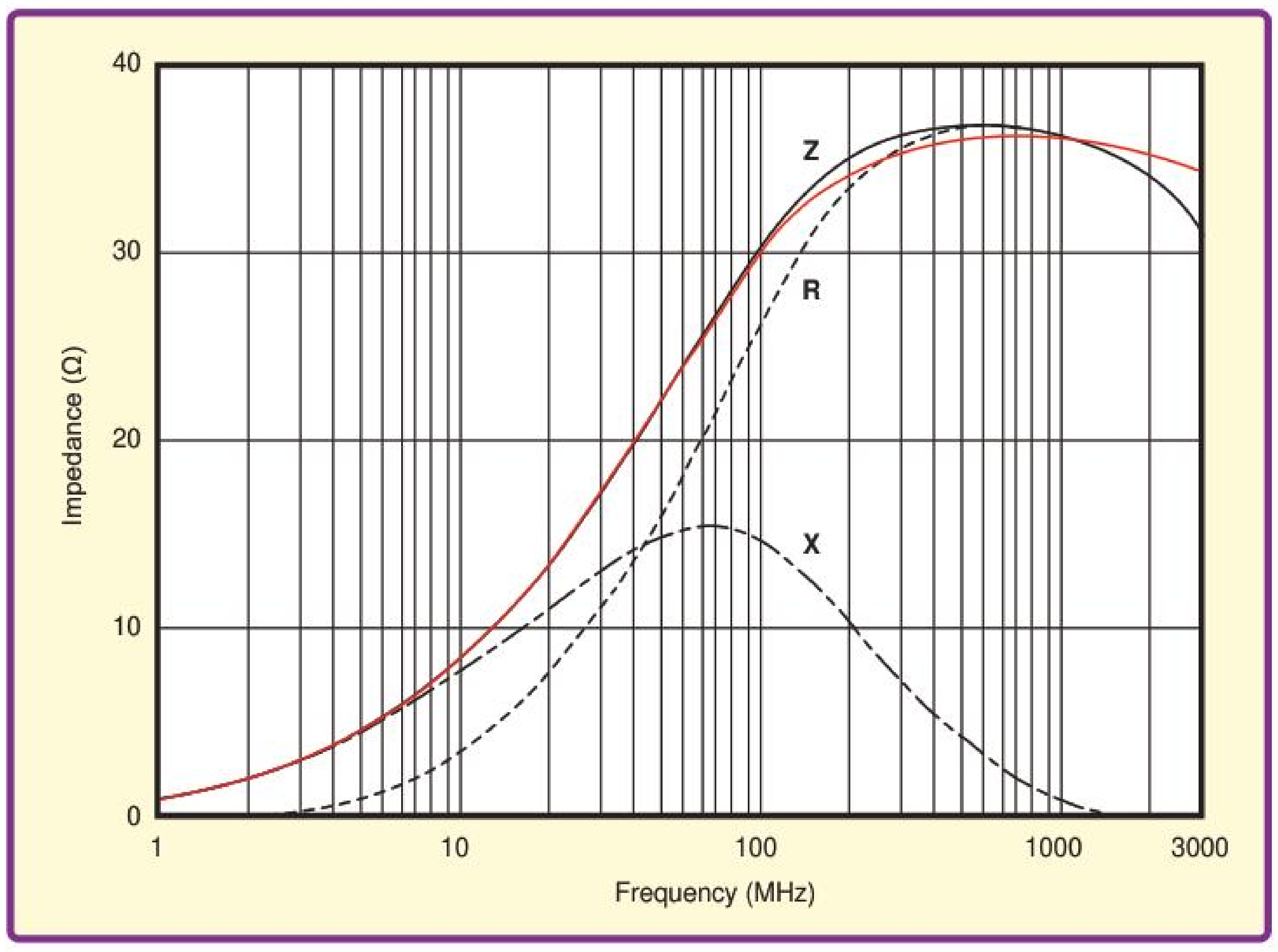


Fig.16. Comparison of the datasheet impedance-frequency characteristics of the BLM18KG300TN with the SPICE model provided by Murata (Fig.14 and Fig.15). The simulated curve is shown in red

Frequency dependence

Earlier, we discussed the fact that ferrite bead inductance and resistance vary with frequency, unlike ideal components whose value is independent of frequency. The SimSurfing software is able to plot the values of inductance and resistance against frequency for a chosen bead. The graphs for the BLM18KG300TN1 are shown in Fig.17 and 18. The resistance curve is effectively the same as Fig.1. The Inductance curve explains why no inductance value is given on the datasheet – there is no fixed value to give. However, we can see that the value of 87nH, which we tried earlier is indeed the value at 20MHz and since it is close to the middle of the curve in Fig.18, it probably represents a reasonable best guess if we have to use a single value.

Like the simple single-inductor model, the SPICE model from Murata uses inductors and capacitors which do not vary with frequency. It is possible to model frequency-dependent resistors and inductors in SPICE, for example by using a behavioural voltage-controlled current source configured with Laplace equations and these may give more accurate results. In all cases though, it is necessary to find the right numbers to put into the model (which brings us back to ***741's*** original question). As we saw with the single-inductor parasitics model earlier, this is not necessarily easy – and it gets more difficult with more complex models such as that in Fig.15. Fortunately, companies like Murata usually do the job for you in their published models. To actually get the numbers you have to do something like use a vector network analyser to characterise the real components and then use software to fit the data to your chosen model, compensating for the impedance characteristics of the test fixtures.

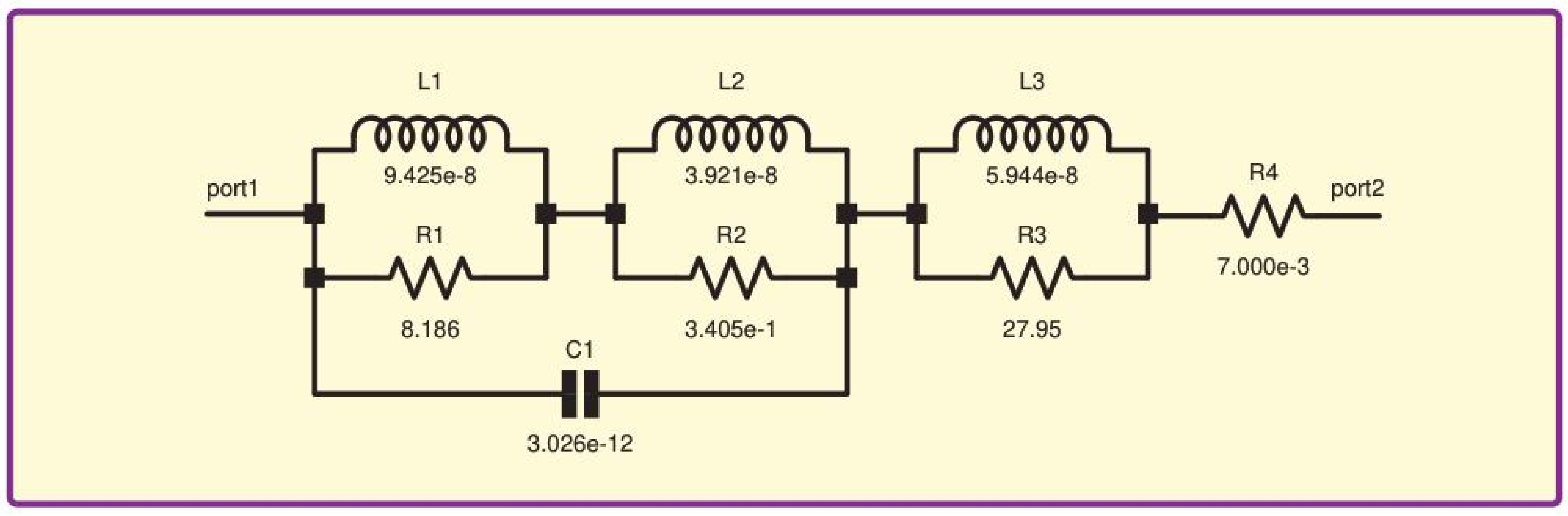


Fig.15. Schematic of Murata's SPICE model of the BLM18KG300TN1

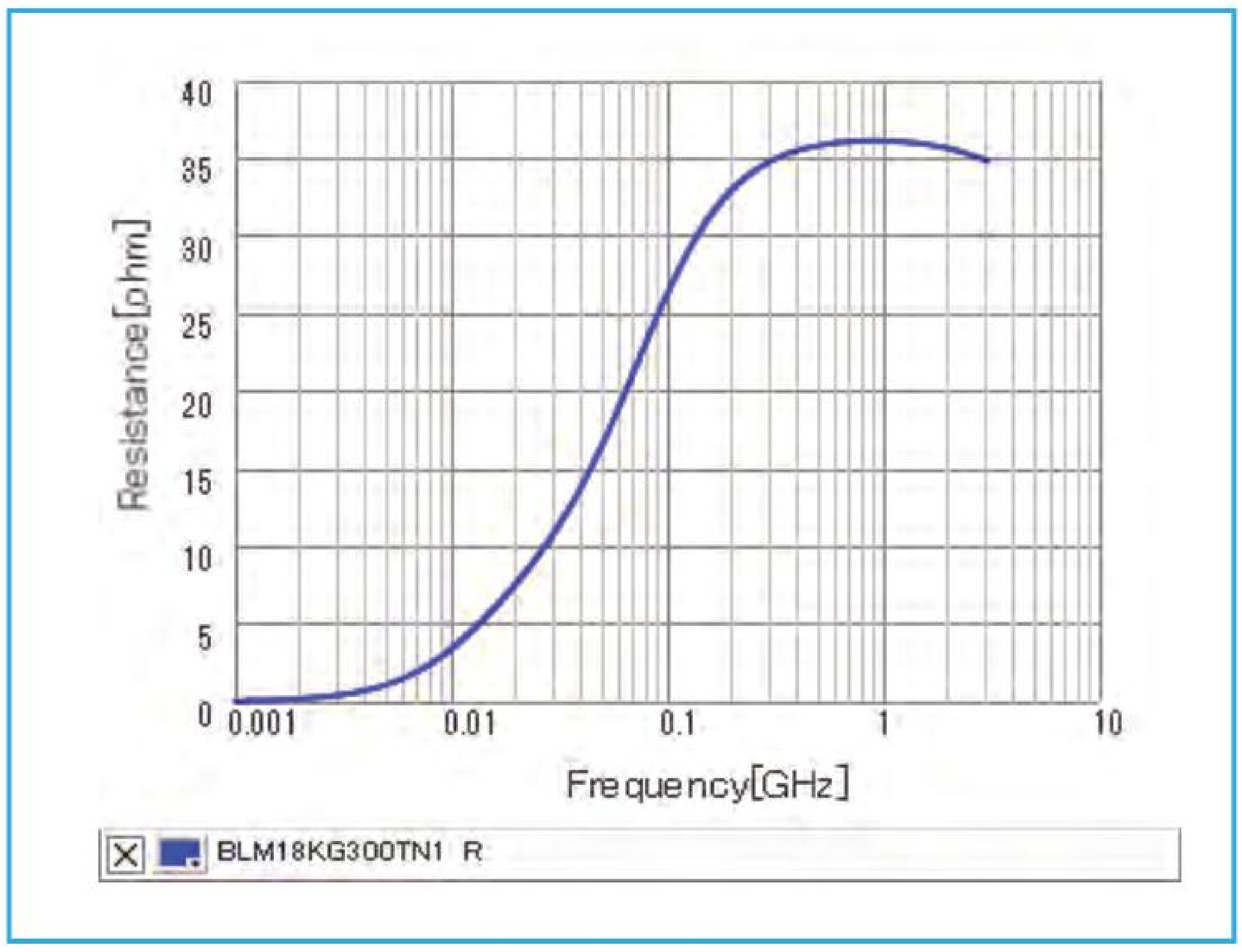


Fig.17. Screenshot from Murata's online SimSurfing software showing variation of the resistance of the BLM18KG300TN1 with frequency

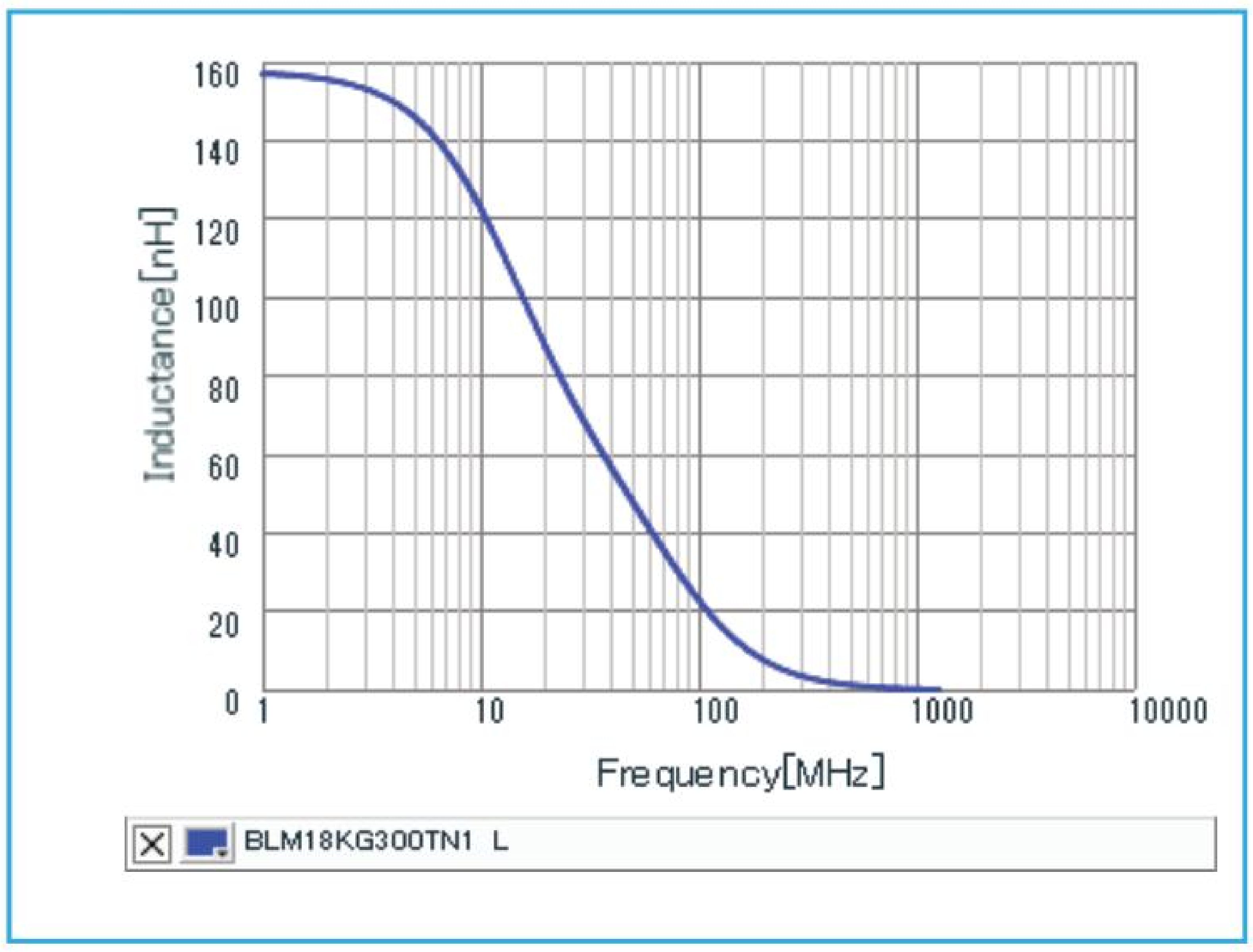


Fig.18. Screenshot from Murata's online SimSurfing software showing variation of the inductance of the BLM18KG300TN1 with frequency

PIC n' Mix

Mike O'Keeffe

Our periodic column for PIC programming enlightenment

Managing software

IT'S the New Year and it's time to write up our New Year's resolutions. What better, than to develop and manage our designs, schematics and software in a safe and controlled fashion?

Last month, we built our very own *PICmas Tree* using a software-controlled method called 'Charlieplexing'. This allowed us to individually control 56 LEDs using only eight GPIO pins. I developed some basic code for this, which you can download the from the *EPE* website. Wouldn't it be nice if we could all share our code in the one place, maybe even modify and add to each others code easily and without any problems? This is where software management comes into play.

There are a few things we need to look at in order to understand how to effectively manage our software. From the language we use and tracking bugs, to where and how we store it and then share it with the world. We're going to look at compilers, integrated development environments (IDE), repositories, version control and bug tracking.

Compilers

Compiler are pieces of software that transforms our code, written in a programming language (like C, C++ and even assembly) into another language that can be interpreted by our destination system. For example, last month's *PICmas Tree* code, which was written in C using Microchip's MPLAB X IDE, compiled using Microchip's XC8 compiler into a binary hex file, and then loaded onto our PIC18F, via the PICKIT 3 programmer.

Microchip have developed four compilers for their PIC and dsPIC products. XC8 is used for their 8-bit microcontrollers, XC16 for their 16-bit microcontrollers and XC32 for their 32-bit microcontrollers. These are all C compilers. The fourth compiler is called XC32++, developed specifically for C++ development on the PIC32 microcontrollers. These are all available in free, standard and 'PRO' editions. The free edition has no memory or time restrictions, supports all the devices and commands of the standard and PRO editions – the only limit is the code optimisations. The standard edition offers 20-25% code optimisation and the PRO edition offers 50% code optimisation, giving you the most efficient memory usage. The PRO version allows you to write up to twice the amount of code into the same micro. The free edition would be the most appealing to the majority of people.

It is also useful to mention that in Microchip's previous IDE (MPLAB 8.x), the compilers used were called C18, C30 and C32. These are only compatible with the older IDE and should *not* be used with MPLAB X.

I reviewed Mikroelectronika's mikroC for the PIC32 back in October. They also have their own compilers, mikroC PRO, mikroBASIC PRO and mikroPascal PRO for the PIC, dsPIC and PIC32 microcontrollers. These are actually a compiler and IDE in one, which natively support the PICs. This offers the developers the option to develop their code in either C, BASIC or Pascal, which is an interesting option. The only disadvantage here is having to purchase mikroC for PIC, mikroC for dsPIC/PIC24 and mikroC for PIC32 to cover the entire PIC range, on top of their own mikroProg programmer in order to program and debug your application.

Integrated development environment (IDE)

IDEs offer a controlled method of software project management, allowing us to develop multiple software projects simultaneously. These help to keep all our project files in the same directory, as well as having the ability to compile our code (with the XC8, XC16, XC32 compilers attached), debug our code, add software and hardware breakpoints and step through each line. It's this last part – debug – which is the most powerful asset. Normally, we use Microchip's MPLAB X IDE (previously, we used MPLAB 8.x), which is a free development environment specifically designed for use on Microchips PIC and dsPIC microcontrollers. If you've ever programmed or used a PIC before, you're probably well aware of this tool.

However, it is not the only IDE on the market and it's always a good idea to know what the other options are. There are a few other IDEs that can be used to develop your code. Eclipse is one of the most popular development environments, it's both free and open source software. It has a basic workspace and a wide range of plug-ins that allow it to support a range of programming languages, such as C++, COBOL, Fortran, Haskell, Javascript, Lua, Perl, PHP, Prolog, Python, Ruby and many more. However, it does not natively support the PICs and may be difficult to set it all up.

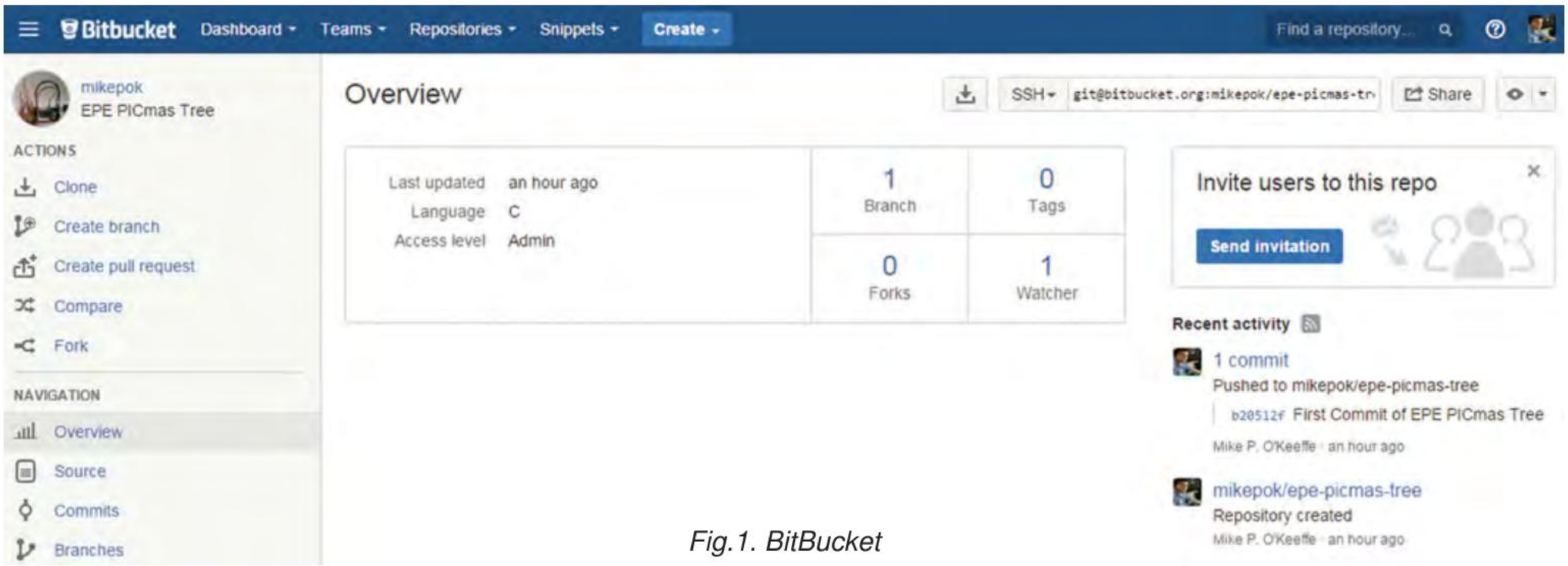
Microsoft's Visual Studio or Visual Studio Express can also be used to develop code in, but it is not straightforward. Visual Studio is specifically designed for developing code for the Windows operating systems.

As I mentioned above, Mikroelectronika's mikroC for PIC is both a compiler and an IDE. They support the majority of PIC controllers. The great thing about mikroC is the number of built in libraries (called Libstock) that give you the ability to write programs quickly and efficiently for a wide number of applications including FFT, I^{2}C, Manchester encoding, memory manager, OneWire interfaces, TFT, UART, USB ... to name but a few.

If you are used to one IDE and prefer to use it, then you may be best served by sticking with it. I must add that I highly recommend both Microchip's MPLAB X and Mikroelectronika's mikroC IDE's for ease of use. Both of them natively support the PIC microcontrollers and will not need extensive work trying to get them to work together. The other main advantage is the ability to debug and step through your code, which none of the other IDEs easily support. The MPLAB X IDE and its compilers XC8, XC16 and XC32 are all available for free, which make them the most appealing IDE and compilers to work with.

Repositories and version control

A repository, in the context of software management, is a storage location where we can safely store our software to be retrieved at any time by anyone we choose. They can reside locally on your own machine, on a remote server on a private network, or up in the cloud. The main idea here is to keep our code safe, in case something happens to it. These are usually coupled with version control systems (VCS), which allow us to control each version of code and revert to a previous version if necessary. Each version usually has a unique version number (ie, version 1.2.14), a timestamp of when it was uploaded to the repository and the name of the person making the change. There are



git@bitbucket.org:mikepok/epe-picmas-tr

Last updated: an hour ago
Language: C
Access level: Admin

1 commit
Pushed to mikepok/epe-picmas-tree
b20512f First Commit of EPE PICmas Tree
Mike P. O'Keeffe · an hour ago

mikepok/epe-picmas-tree
Repository created
Mike P. O'Keeffe · an hour ago

Fig.1. BitBucket

many other advantages to this, including the ability to store the historical records of changes made to files. It gives us a chance to view the line-by-line changes made to code. This is an incredibly useful tool and can often save us when we've made some changes, which allows us to revert to a previously working piece of code instead of painstakingly searching through our code to find that one little mistake.

There are a few things we need to consider when choosing software repositories:

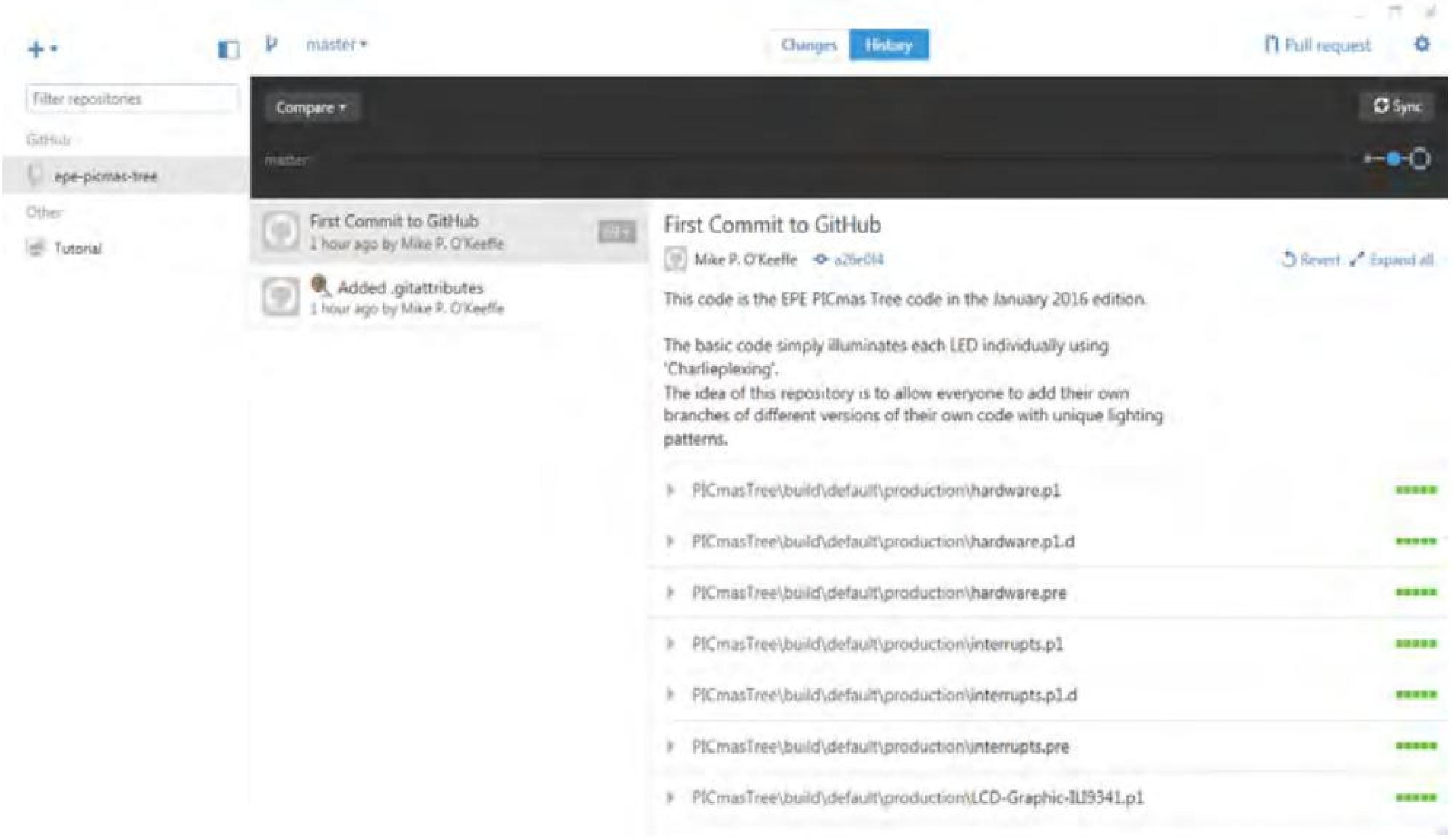
1) Cost
2) Private versus public access
3) Ease of use
4) Online versus local storage
5) The addition of a VCS

When it comes to cost, I have to admit, I love free. Who doesn't? The best thing here is most of the online repositories and version control systems are free (or under the open-source GNU licence). There are quite a number of repository and VCS packages, including: GitHub, Git, BitBucket, SourceForge, CVS, Jazz RTC, Stash, IBM's Rational ClearCase, Microsoft's Team Foundation Server, Mercurial and Subversion.

It's not possible to go into each one and compare all of their individual advantages. In fact, I find too many options tend to confuse and frustrate. Let's simply look at two of the most popular: GitHub and BitBucket. They are both based off 'Git', which is a popular VCS. GitHub and BitBucket are repository hosting services. The main difference between the two is that GitHub is publicly accessible by everyone by default and can only be made private by upgrading to a monthly price plan. BitBucket, on the other hand, provides private access by default and up to five user accounts to access the repository. Alternatively, you can also make your BitBucket repository public as well. BitBucket was developed by Atlassian and also works natively with a number of other software management tools like Stash, JIRA, Confluence, Bamboo and HipChat. See Fig.1 for a screenshot of BitBucket.

The thing I love most about GitHub and BitBucket are the free, easy-to-use GUI interfaces that you can download for them; GitHub Desktop (see Fig.2) and SourceTree (for BitBucket, See Fig.3). It is unfortunate they only work on Windows 7 or later. If you're using Windows XP, you'll have to use the git command prompt or Git GUI, which is not as handy. In fact, if you check out my repositories below, they will actually give you the exact command you would use to download from the repositories. See Fig.4 for an example of using Git in the command line.

When it comes to repositories and version control, there are a few useful phrases that need to be understood. These often cause confusion. Here's a quick breakdown of some of the common vocabulary that you will need to know.



First Commit to GitHub
1 hour ago by Mike P. O'Keeffe

Added .gitattributes
1 hour ago by Mike P. O'Keeffe

First Commit to GitHub
Mike P. O'Keeffe a2be014

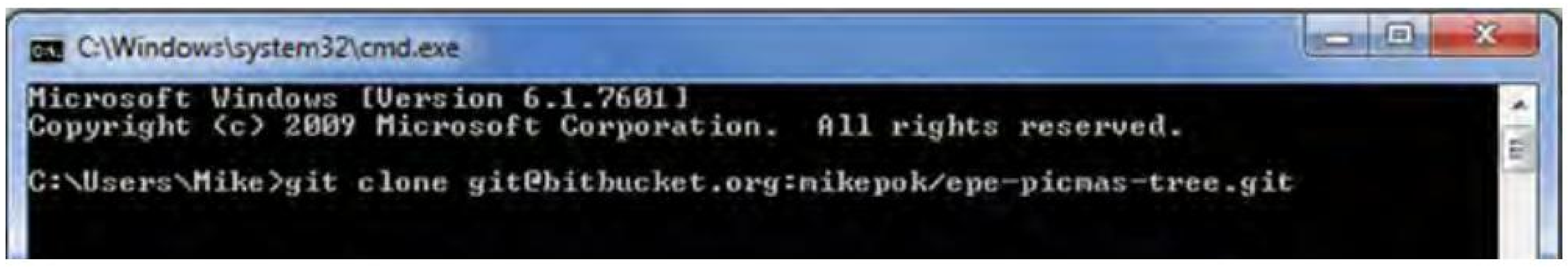
This code is the EPE PICmas Tree code in the January 2016 edition.

The basic code simply illuminates each LED individually using 'Charlieplexing'.
The idea of this repository is to allow everyone to add their own branches of different versions of their own code with unique lighting patterns.

PICmasTree\build\default\production\hardware.p1
PICmasTree\build\default\production\hardware.p1.d
PICmasTree\build\default\production\hardware.pre
PICmasTree\build\default\production\interrupts.p1
PICmasTree\build\default\production\interrupts.p1.d
PICmasTree\build\default\production\interrupts.pre
PICmasTree\build\default\production\LCD-Graphic-ILI9341.p1

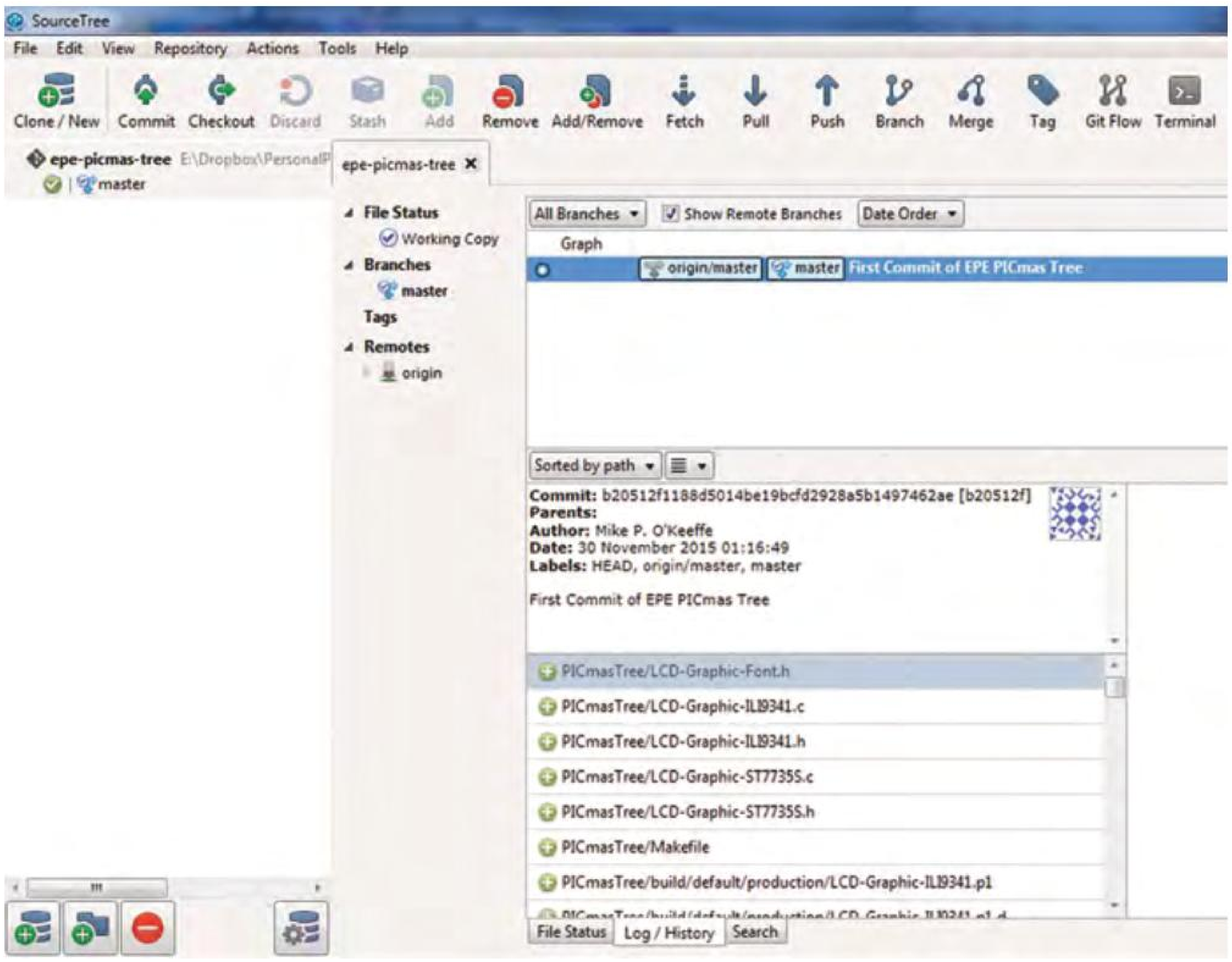
Fig.3. Git Hub Desktop

1) Branch – (aka 'Fork') a set of files that have been split in two, which will be developed independently of each other
2) Checkout – creating a local working copy from a repository, in order to be modified
3) Clone – copying an existing repository to another repository, locally or remotely
4) Commit – (aka 'Check in') write or merge existing changes from the working copy back to the repository
5) Head – (aka 'Tip') refers to the most recent commit to either a trunk or a branch
6) Merge – two sets of files from two or more developers apply their changes to the same repository. The changes are merged and tracked. This could include merging from a branch back to the trunk
7) Pull – (aka 'Fetch') copy from one repository to another, initiated by the receiving repository
8) Push – similar to Pull, where we copy from one repository to another, but initiated by the source repository
9) Trunk (aka 'Baseline', 'Mainline' or 'Master') the main or unique development that is not a branch
10) Working Copy – local copy of files, these are the files you will be working from before they are committed



```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\Mike>git clone git@bitbucket.org:mikepok/epe-picmas-tree.git
```

Fig.2. Git Command Line


SourceTree
File Edit View Repository Actions Tools Help
Clone / New
Commit
Checkout
Discard
Stash
Add
Remove
Add/Remove
Fetch
Pull
Push
Branch
Merge
Tag
Git Flow
Terminal
epe-picmas-tree
master
File Status
Working Copy
Branches
master
Tags
Remotes
origin
All Branches
Show Remote Branches
Date Order
Graph
origin/master
master
First Commit of EPE PICmas Tree
Sorted by path
PICmasTree/LCD-Graphic-Font.h
PICmasTree/LCD-Graphic-ILI9341.c
PICmasTree/LCD-Graphic-ILI9341.h
PICmasTree/LCD-Graphic-ST7735S.c
PICmasTree/LCD-Graphic-ST7735S.h
PICmasTree/Makefile
PICmasTree/build/default/production/LCD-Graphic-ILI9341.p1
File Status
Log / History
Search

```
Commit: b20512f1188d5014be19bcfd2928a5b1497462ae [b20512f]
Parents:
Author: Mike P. O'Keeffe
Date: 30 November 2015 01:16:49
Labels: HEAD, origin/master, master

First Commit of EPE PICmas Tree
```

Fig.4. SourceTree

It is easy to get confused by all the terms. I find the easiest way to understand it all is as follows: start off with cloning from our repository to our working copy, make our changes and commit our changes before pushing back up to the main repository. Stick to this flow and you'll be fine. Getting more complicated than that, you can commit to your own branch and merge it back to the trunk again at a later date.

Why not give both GitHub and Bibucket a try and see which you prefer. I've placed last month's code on both, feel free to clone and create your own fork to share with the world:

https://github.com/mikepokeeffe/epe-picmas-tree

https://bitbucket.org/mikepok/epe-picmas-tree

Just as an addendum, I mentioned at the start of the article, that we can manage and control all software. This includes any files we might be developing, including documents, EagleCAD schematics, PDFs and even binary files. Most VCS operates very well with pure text files, which is what most files are. Binary files or proprietary file formats like PDFs can be still be stored, but we cannot easily see line-by-line changes.

Bug tracking

The term 'bug' is actually quite old, originally used in mechanical systems, where insects or bugs were found to have been the cause of system malfunctions.

It's easy enough to write small amounts of code without problems. The difficulty begins to show when our code starts to grow or we start developing with others. This is where the ability to track problems or bugs in our code becomes apparent. Taking last month's code, I've uploaded it to two separate repositories, where anyone can branch or fork their own versions of the code. With multiple code revisions on two separate repositories, merging the two could become painful. The VCS handles this nicely. But, how do we track or monitor if bugs are fixed in one repository and not in the other?

There are a number of bug tracking systems out there. Some are stored in the cloud (remotely) and others can be installed locally. For a small number of bugs, it's not uncommon to use a text file or a spreadsheet. To be honest, bug tracking is entirely optional, but extremely useful. When the code grows and there are multiple revision numbers, we need to know which bug was fixed in which revision. There is a huge variety of bug trackers available, including JIRA, Zoho Projects, Planio, BugZilla, ManitsBT, IBM Rational, and Axosoft.

JIRA is another Atlassian product that works directly with BitBucket above. Unfortunately it's not free, at $10 per month for up to 10 users. We could use Bugzilla as well, but it really is designed for finding bugs and issues in Mozilla Firefox itself or other websites. Zoho Projects is another popular bug tracking package that is free for one project and $20 per month for up to 20 projects. See Fig.5 for an example of Zoho Projects, where I have started a number of bugs for the *PICmas Tree*.

In any bug tracking system we want to record the following data, there are number of other fields we can add in as well at our discretion, but these are the basic pieces we need:

1) Descriptive name of bug
2) Short description
3) Assignee – the person who is going to fix the bug
4) Reproducible – can it be reproduced? / description of reproduction.
5) Severity – is it a minor, major, critical issue or a suggestion?

Bug trackers usually include project management (resources, milestone, goals and deadlines), time tracking, charting software and much more. This makes tracking software much more valuable.

Next month

Wrapping it all up, software management is completely scalable and very useful. As any project grows, the need for decent monitoring and control becomes more apparent. Next month, we're going to look at another little project using a pyroelectric PIR motion sensor (passive infrared sensor) and how they work.

Not all of Mike's technology tinkering and discussion makes it to print. You can follow the rest of it on Twitter at *@MikePOKeeffe*, up on *EPE Chat Zone* as *mikepokeeffe* and from his blog at *mikepokeeffe.blogspot.com*

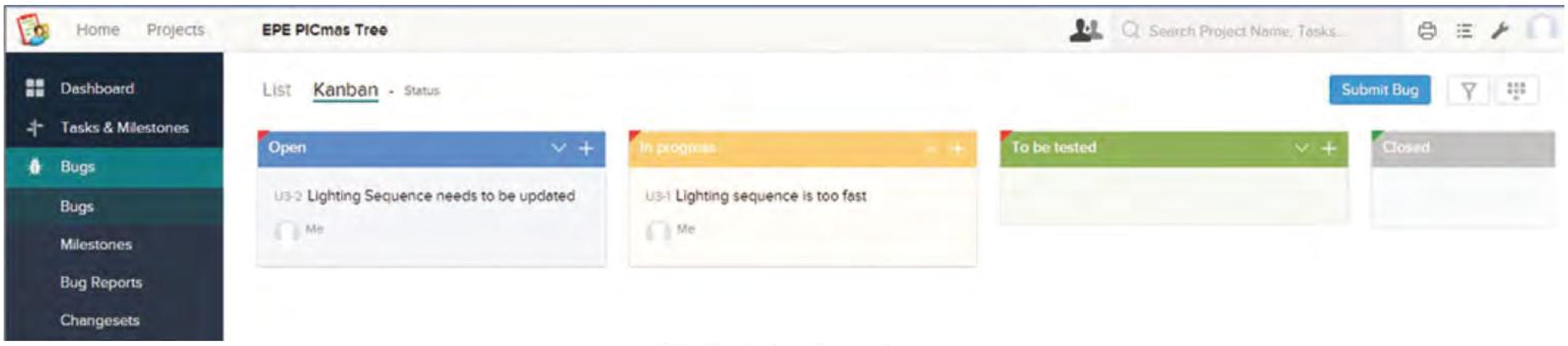

Home
Projects
EPE PICmas Tree
Search Project Name, Tasks...
Dashboard
Tasks & Milestones
Bugs
Bugs
Milestones
Bug Reports
Changesets
List
Kanban
Status
Submit Bug
Open
In progress
To be tested
Closed
U3-2 Lighting Sequence needs to be updated
Me
U3-1 Lighting sequence is too fast
Me

Fig.5. Zoho Projects.

AUDIO OUT

By Jake Rothman

Speaking volumes – Part 3

Data sheet disaster

I once ordered lots of expensive BI Technologies P260 one-million cycle conductive plastic pots from Profusion, see Fig.39. Unfortunately, they didn't work properly as stereo volume controls, but met all the makers' specs, so I couldn't send them back. If a parameter isn't specified on the data sheet you can't complain if it's bad. The problem was that one track would always start up before the other. I pulled one apart to investigate and found the cause was the construction. Inside was a small ceramic disc on which was printed the track and collector ring. The problem was a small amount of play, which allowed the disc to move a little relative to the wiper. Twisting the case and even drilling out the rivets couldn't fix the misalignment. A shame, since the pots had an excellent 'feel' and solid metal shafts.

Back to Blumlein

To try and save face and a few hundred quid, I had to develop a circuit to use them. I had an idea, which originally stemmed from the RIAA rumble filter described in *Audio Out* September 2015. I went back to Blumlein's original sum and difference circuit patent of 1931 and put the mono (sum/middle) information through one track and the stereo (side/difference) information through the other. This would then be converted back to standard stereo and the system is shown in Fig.40. Since most of a stereo signal is common to both speakers, channel imbalance couldn't occur if the mono information was sent through one pot track. Blumlein had to do this with expensive transformers, but nowadays, it only takes a few op amps to do this (and they're 15-times cheaper than the pots). I like to think I invented this pot dodge – but generally, in analogue there's nothing new under the sun.

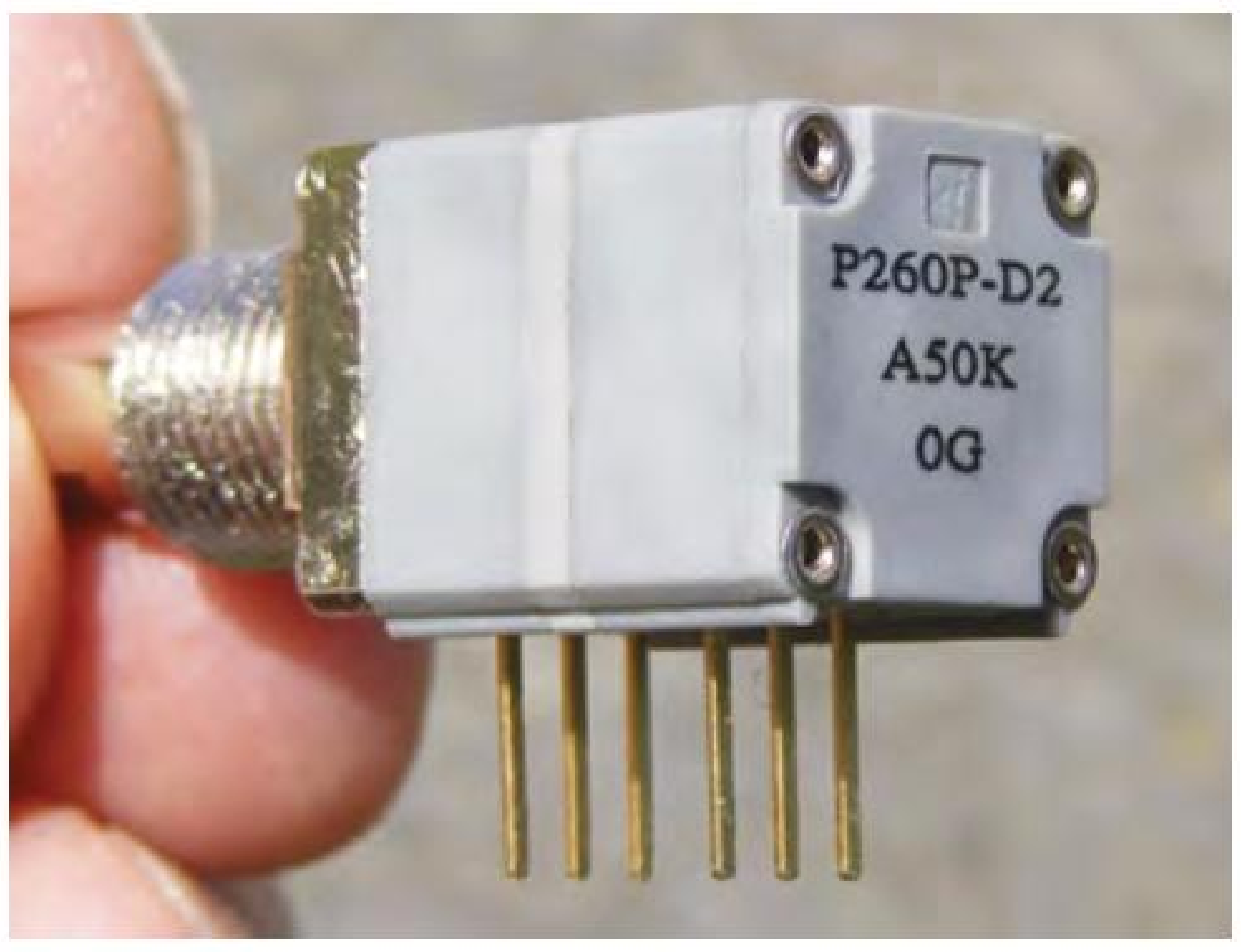


Fig.39. BI technology dual conductive plastic pots – the two tracks didn't start up at the same time

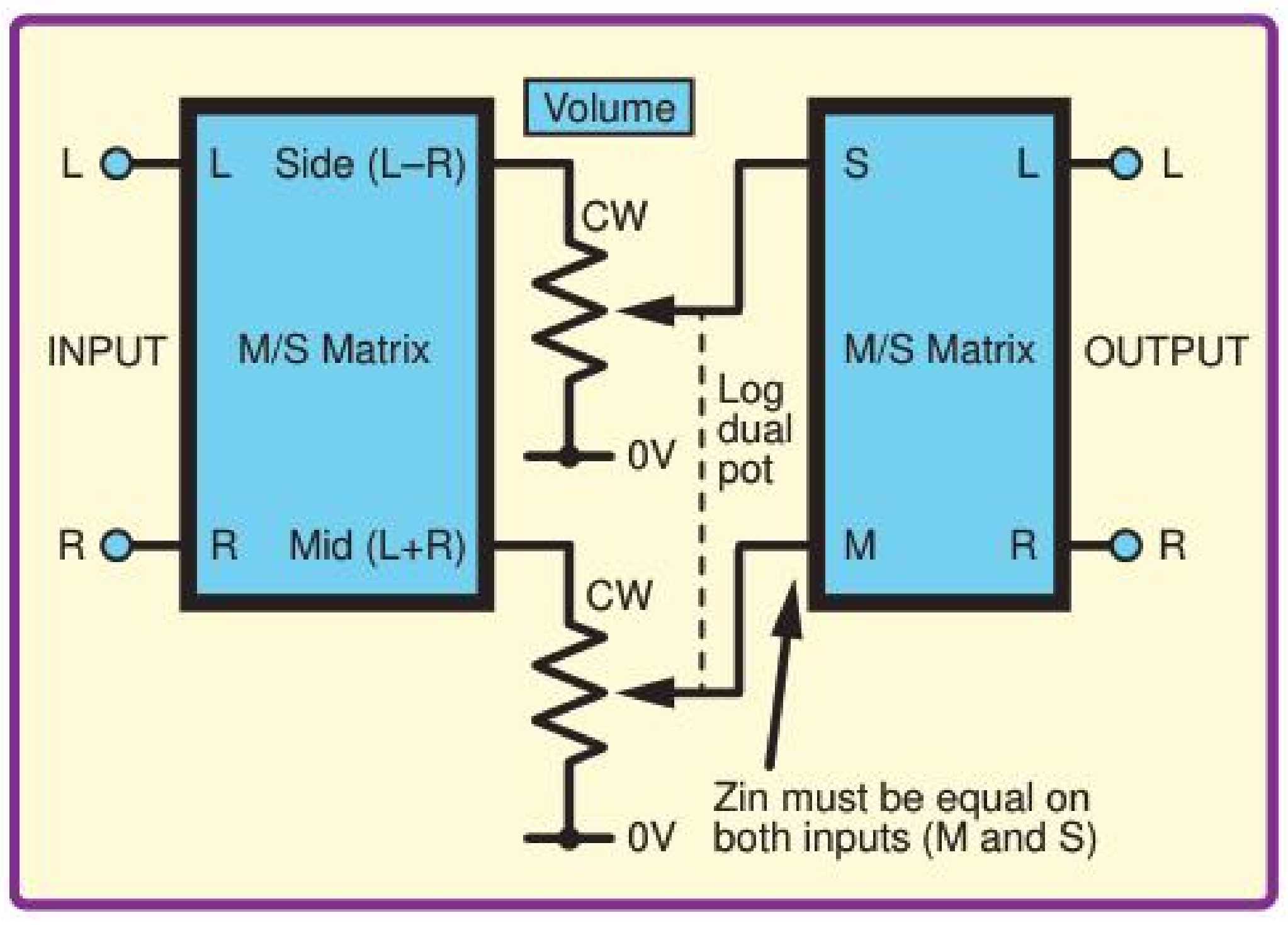


Fig.40. Middle and side volume control – the mono signal goes through one track, stereo information through the other. This way, stereo wandering as the pot is rotated is rendered inaudible

The complete circuit is shown in Fig.41 and a photo of the board in Fig.42. Deriving the M (middle) signal is simple, it's just the left and right summed together. The side signal is the difference, so we need a differential amplifier or summer with one input inverted to derive this. These signals are then fed into a standard log dual-gang pot. To convert back to normal stereo, we have to employ the sum and difference processing again. (Note that I've used my normal capacitor distortion reduction tricks, which I covered in the August to October 2014 *Audio Out* articles.) It is essential that the mono side of the pot starts up first, because that is where the bulk of the music is; the side signal on its own just sounds out of phase. This means it is necessary to be able to select that track on the pot. The easiest way to do this is to connect the pot pins to Molex 0.1-inch connectors, as shown in Fig.43. This way, track connections can be easily swapped. In general, it's a good idea to connect pots in this way, since solder flux travelling up the pins can cause havoc with the connection to the track inside. In the later circuit, the 50kΩ pot plugs into a 6-pin DIL socket, as shown in Fig.44.

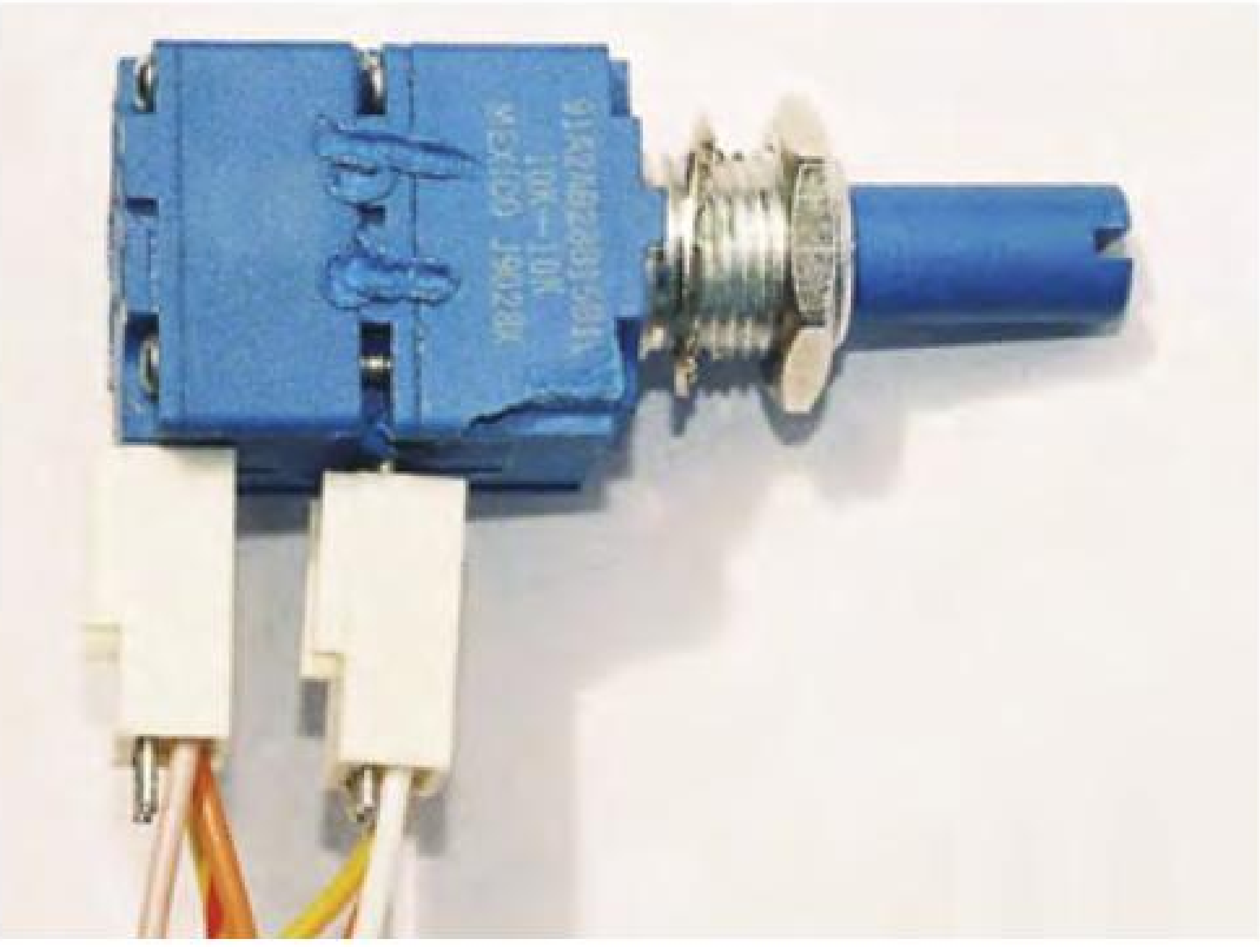


Fig.43. Using Molex connectors allows pot sections to be easily swapped. The soldering iron marks are to lock the two sections together so the channels come up at the same time in a conventional circuit

What's the catch? The mistracking is converted into variations in stereo width as the pot is rotated and crosstalk is also increased. If only one channel is fed in, the stereo mistracking of the pot can be heard as variations in crosstalk across to the unused channel. However, in a

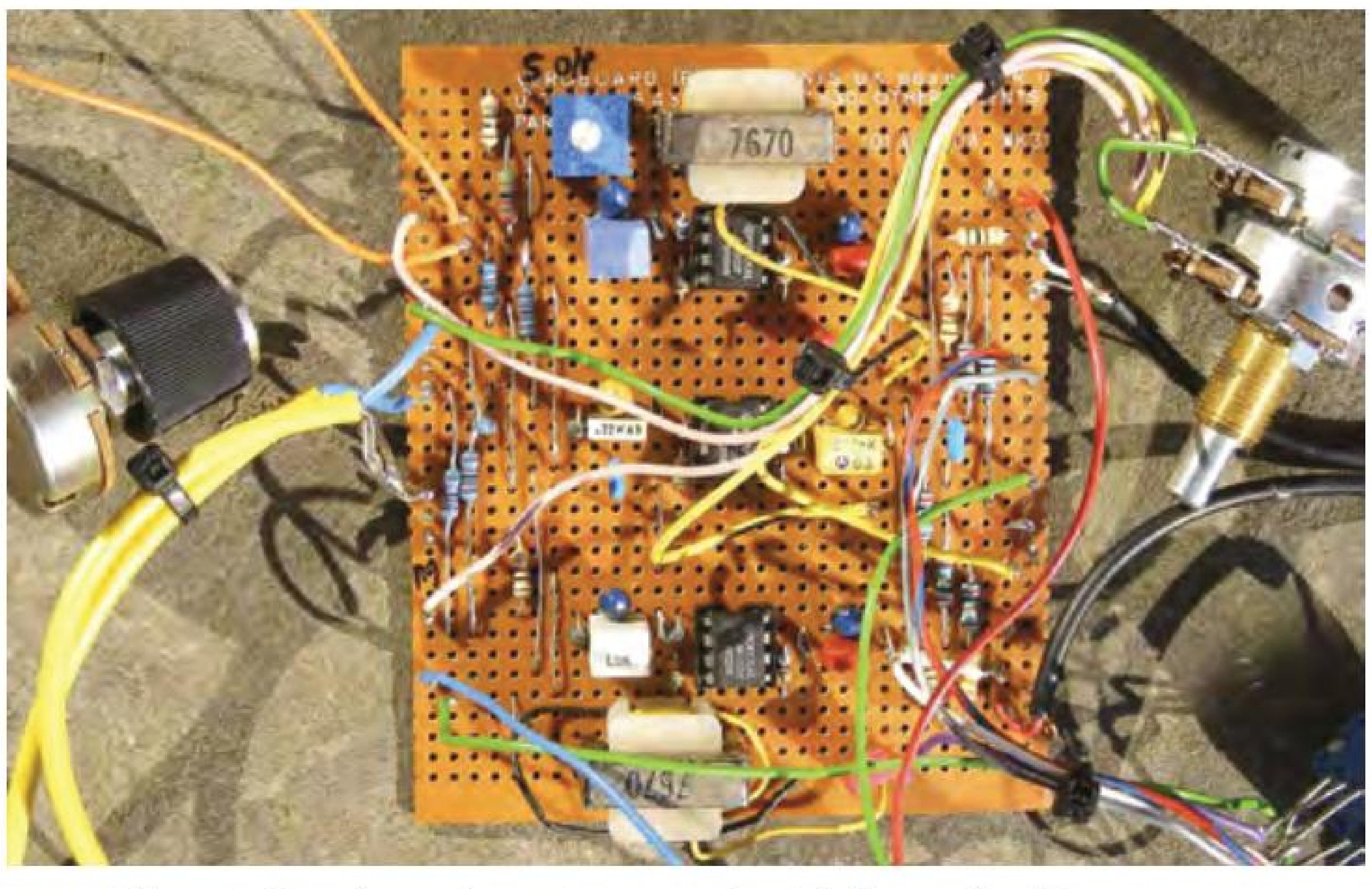


Fig.42. Veroboard prototype of middle and side pre-amp

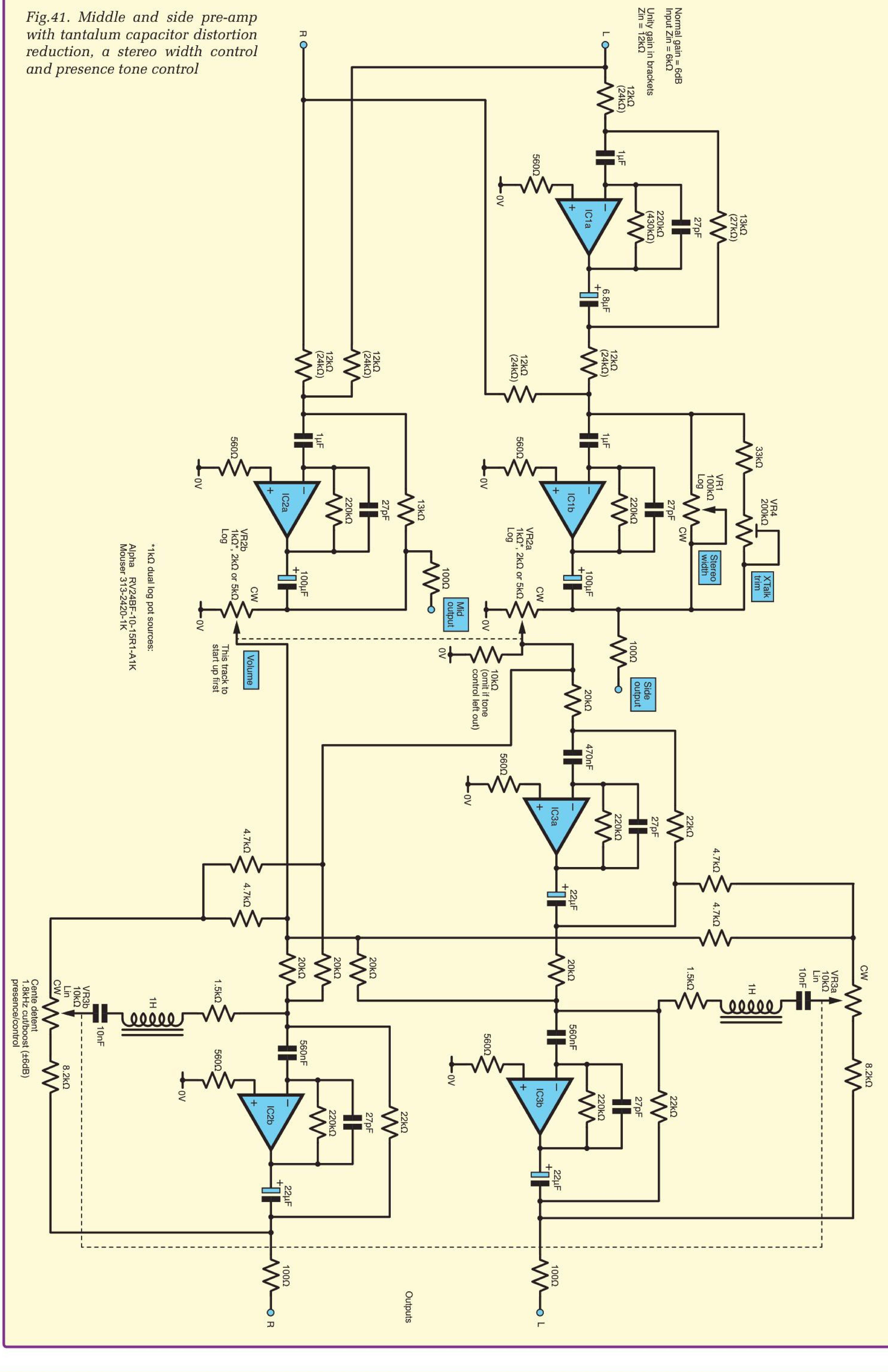


Fig.41. Middle and side pre-amp with tantalum capacitor distortion reduction, a stereo width control and presence tone control

Normal gain = 6dB
Input Zin = 6kΩ
Unity gain in brackets
Zin = 12kΩ
L
R
12kΩ (24kΩ)
1µF
560Ω
0V
IC1a
220kΩ (430kΩ)
27pF
13kΩ (27kΩ)
6.8µF
IC1b
220kΩ
33kΩ
VR1 100kΩ Log
CW
VR4 200kΩ
Stereo width
XTalk trim
100µF
VR2a 1kΩ*, 2kΩ or 5kΩ Log
100Ω
Side output
10kΩ (omit if tone control left out)
20kΩ
470nF
IC3a
22kΩ
4.7kΩ
22µF
IC2a
13kΩ
Mid output
VR2b 1kΩ*, 2kΩ or 5kΩ Log
Volume
This track to start up first
*1kΩ dual log pot sources:
Alpha RV24BF-10-15R1-A1K
Mouser 313-2420-1K
1.5kΩ
1H
10nF
VR3a 10kΩ Lin
VR3b 10kΩ Lin
8.2kΩ
Cente detent
1.8kHz cut/boost (±6dB)
presence/control
560nF
IC2b
IC3b
Outputs

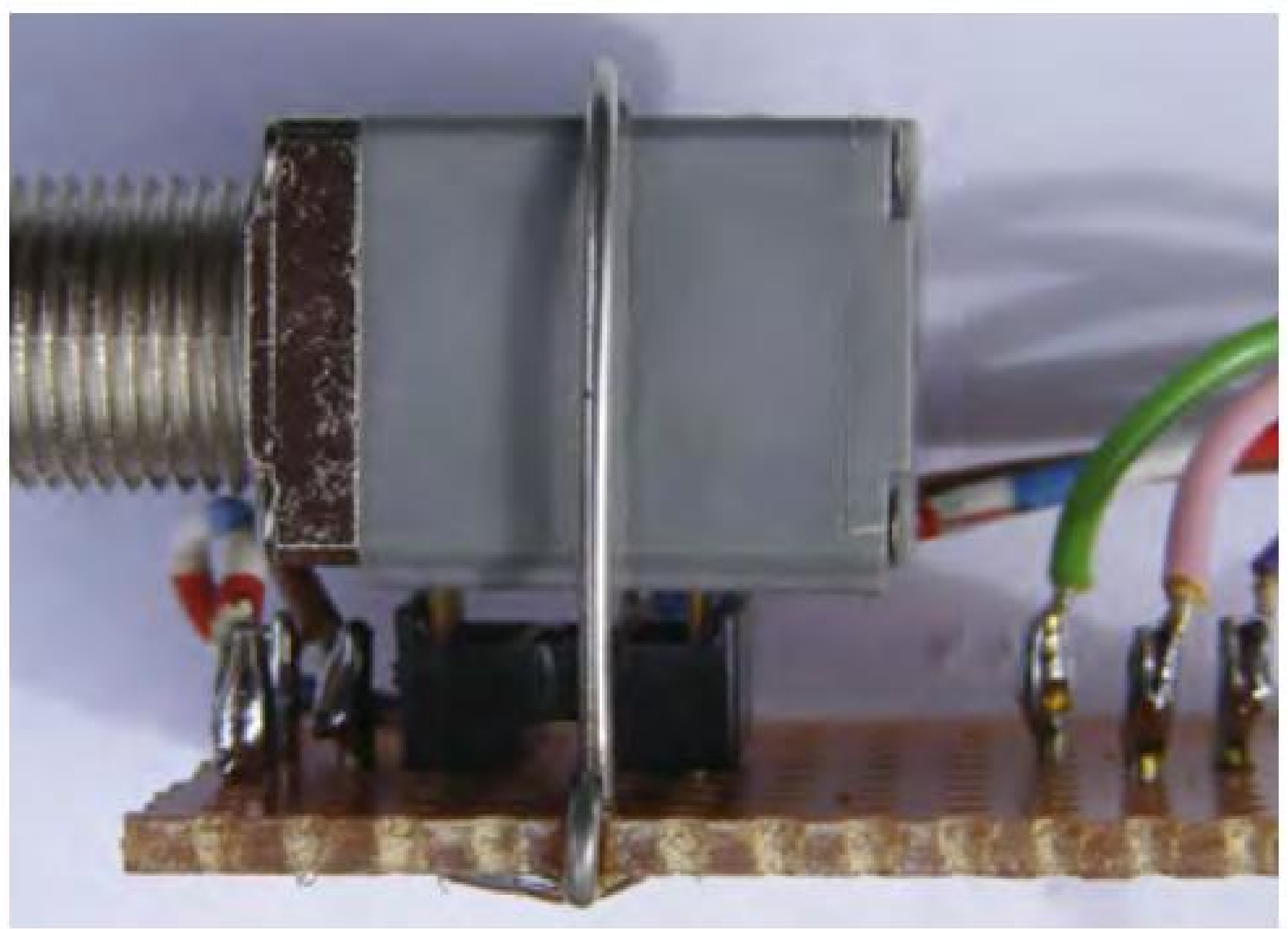


Fig.44. The pins on a P260 pot are spaced such that they can be plugged into a 6-pin DIL socket avoiding soldering

domestic stereo Hi-Fi system, these effects are unnoticeable, certainly much less than the signal swinging between left and right speakers. This circuit has enabled me to use up loads of volume pots I had previously rejected.

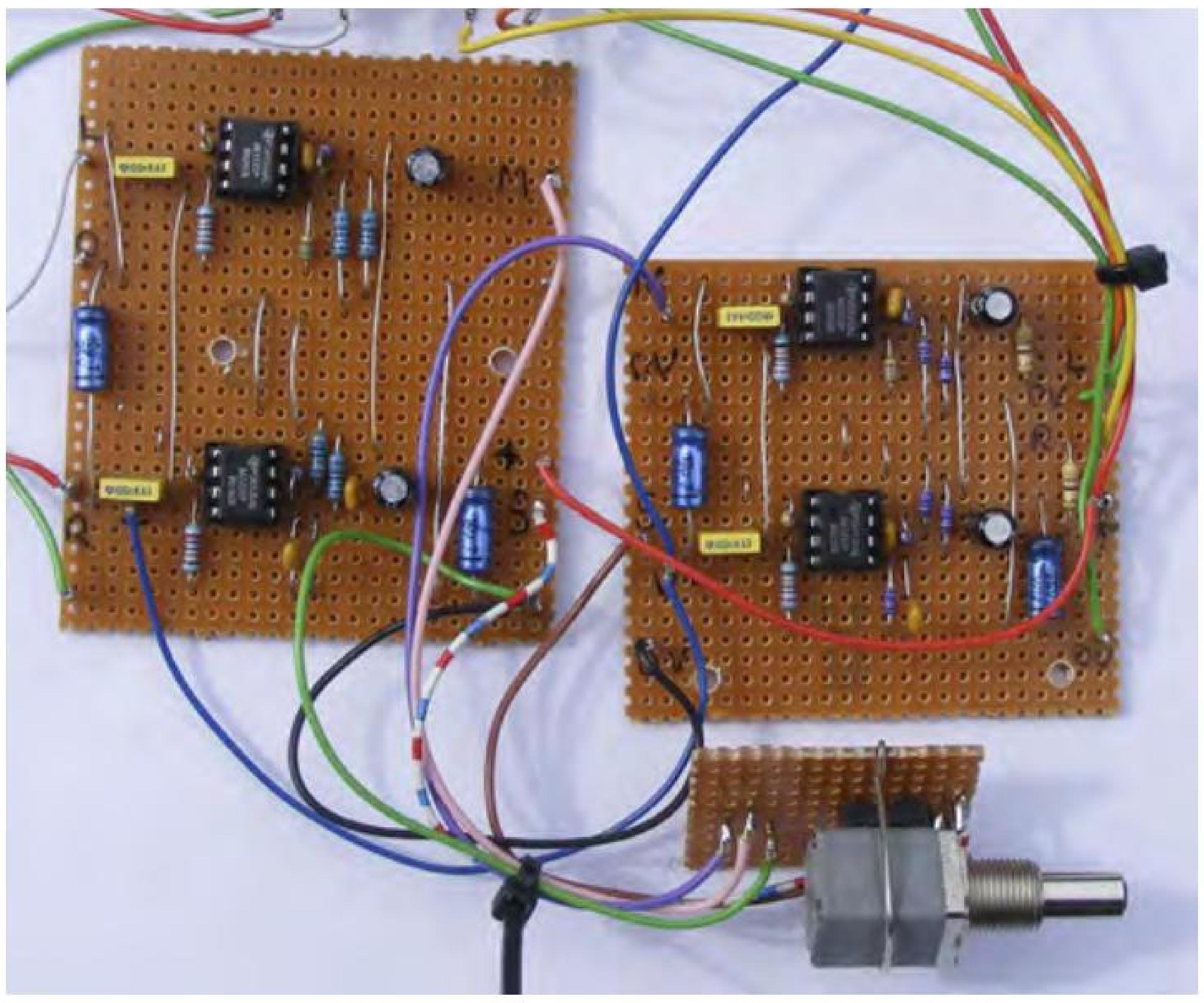


Fig.46. Stripboard prototype of middle and side volume control shown in Fig.45

Since we have a side signal, I decided to take the opportunity to add a stereo width control (VR1), and while I was at it, a tone control too (VR3) – see Fig.41. The circuit uses all inverting stages, so it would be simple to convert it to a discrete design if desired. The trimmer (VR4) deals mainly with tolerances in the stereo width control. To do this, set the control to the middle position, the trimmer is adjusted for minimum crosstalk on both channels. The system has a gain at maximum volume of 6db (2x). This gain is useful for amplifying old-fashioned sources, such as RIAA amplifiers. I've put some theoretical values in brackets for unity-gain, but I've not tested it.

The volume pot (VR2) can be 1kΩ, 2kΩ or 5kΩ log – and yes, the sharp-eyed among you will notice that I'm contradicting my own advice and loading it with only 3.3kΩ (total load). This has the effect of making the pot slightly more logarithmic and introduces slight errors from differences in the track resistance. Since the circuit reduces the subjective effect of pot errors significantly, these effects are relatively negligible. The pot could be reduced in value to 1kΩ to minimise these loading effects. There would be little increase in distortion since the 5532 op amps can drive 600Ω. The 560Ω resistors are a trick I learnt from Kemo Filters. They prevent the high current output of the 5532 destroying its own input protection diodes under fault conditions, such as incorrectly connected power supplies.

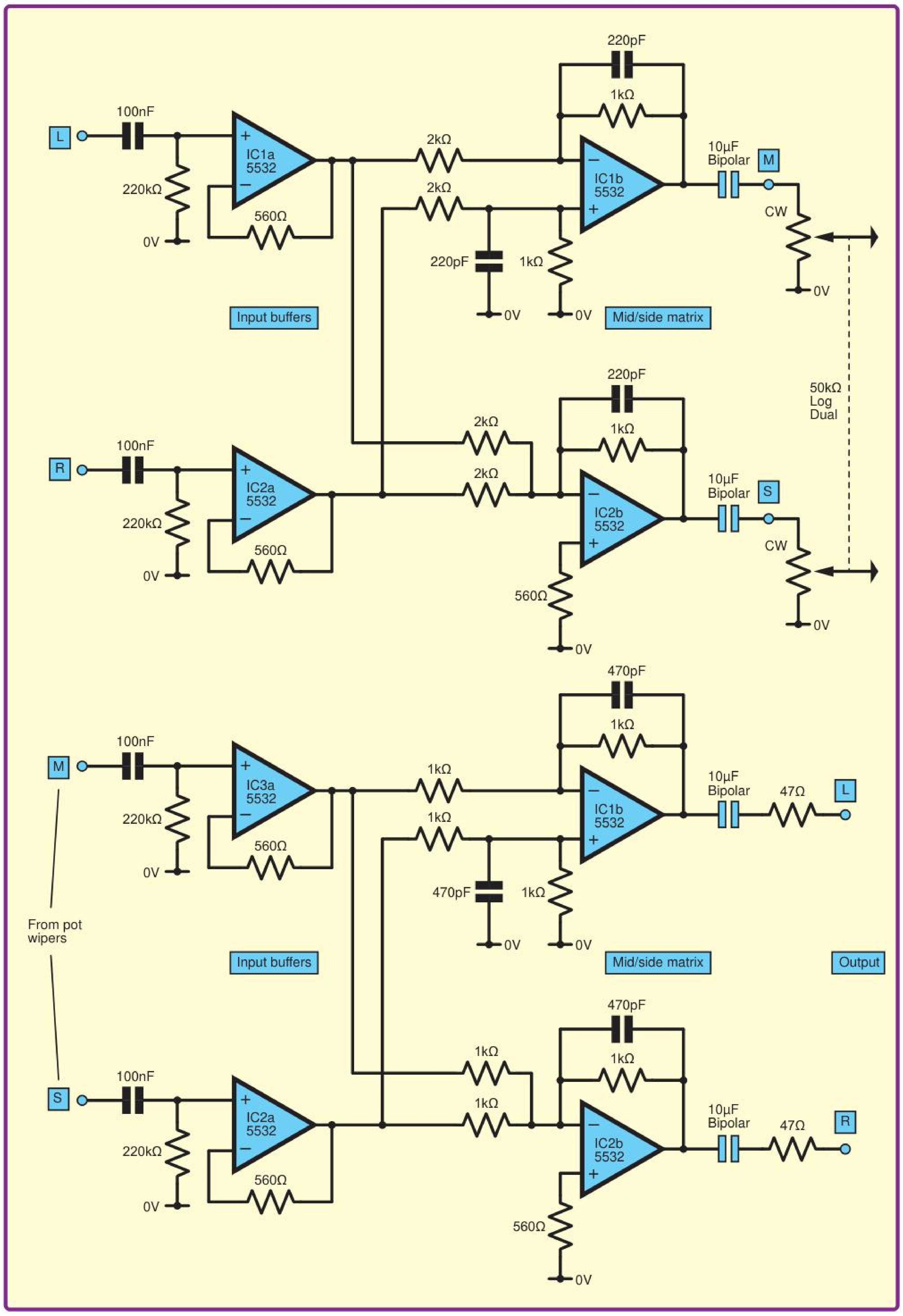

L
100nF
220kΩ
0V
IC1a
5532
560Ω
Input buffers
2kΩ
2kΩ
220pF
220pF
1kΩ
1kΩ
0V
0V
IC1b
5532
Mid/side matrix
10µF
Bipolar
M
CW
0V
50kΩ
Log
Dual
R
100nF
220kΩ
0V
IC2a
5532
560Ω
2kΩ
2kΩ
220pF
1kΩ
IC2b
5532
560Ω
0V
10µF
Bipolar
S
CW
0V
M
100nF
220kΩ
0V
IC3a
5532
560Ω
From pot wipers
Input buffers
1kΩ
1kΩ
470pF
470pF
1kΩ
1kΩ
0V
0V
IC1b
5532
Mid/side matrix
10µF
Bipolar
47Ω
L
Output
S
100nF
220kΩ
0V
IC2a
5532
560Ω
1kΩ
1kΩ
470pF
1kΩ
IC2b
5532
560Ω
0V
10µF
Bipolar
47Ω
R

Fig.45. Simplified middle and side volume control circuit with frills omitted. Suitable for high-value dual log pots

Simplification

Low-value dual log pots are rare, but higher values up to 250kΩ are often encountered. High-value pots give better maximum attenuation, but more noise. If high-value pots are to be used, wiper buffers are necessary. The inputs to the middle and side matrix should be buffered as well, which will add four extra op amps. The buffers enable the resistors in the following inverting op amp circuits to be scaled down (and the caps correspondingly scaled up) to reduce their noise contribution. This is basically the 'low-impedance design' technique developed by Douglas Self. Paradoxically, a buffer followed by an inverting amp with 1kΩ input and

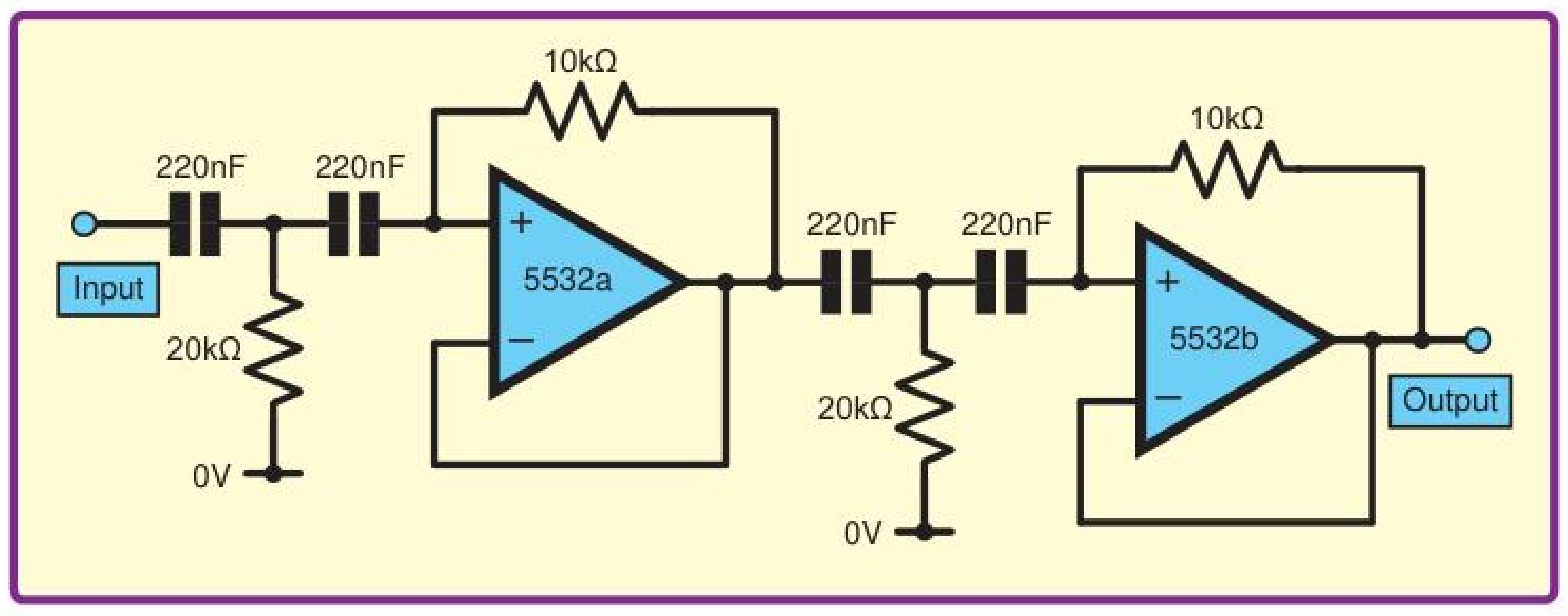

10kΩ
220nF
220nF
Input
20kΩ
0V
5532a
10kΩ
220nF
220nF
20kΩ
0V
5532b
Output

Fig.47. Inserting this high-pass filter in the side signal path reduces rumble from turntables without losing the bass, which normally only resides in the mid signal. Resistor values could be scaled down and the capacitors up to reduce noise

feedback resistors has lower overall noise than just an inverter with 10kΩ resistors. By using buffers, the inverting op amp subtractor circuits can be replaced by differential circuits saving two op amps. This is possible because the differing input impedances of a differential amplifier are no longer a problem, since both inputs are being driven by buffers. Overall, only one extra dual op amp pack is needed. To get a simpler circuit, the capacitor-distortion-reduction circuitry is discarded and bipolar electrolytic capacitors used instead. Also, the tone control and width circuitry is taken out. This results in the circuit shown in Fig.45 and its construction in Fig.46. Unlike the other design, it is better done with op amp chips because of the high drive currents which have to feed the low input impedances.

If all the gain-determining resistors are the same value, the circuit has an overall gain of 6dB. With digital signal sources, gain is not required for volume controls. To give a maximum gain of unity, attenuation is built into the first middle and side matrix circuit, preventing a reduction in headroom. This is why 2kΩ input resistors are used. As explained in *Audio Out* September 2015, a high-pass filter can be inserted in the side signal path to give rumble reduction from vinyl without losing bass. A suitable circuit is given in Fig.47.

Finally, if you're a small manufacturer like me and you have a few dual-gang pots to check for track matching, a jig can be set up, as shown in Fig.48. This shows 0.2-inch Molex sockets for older style PCB mount pots. The differential circuit in Fig.49 can be made if you are a real enthusiast. This is shown in lash-up form in Fig.50. I used this circuit to go through all the P260 pots and I marked which track came up first on all the stock.

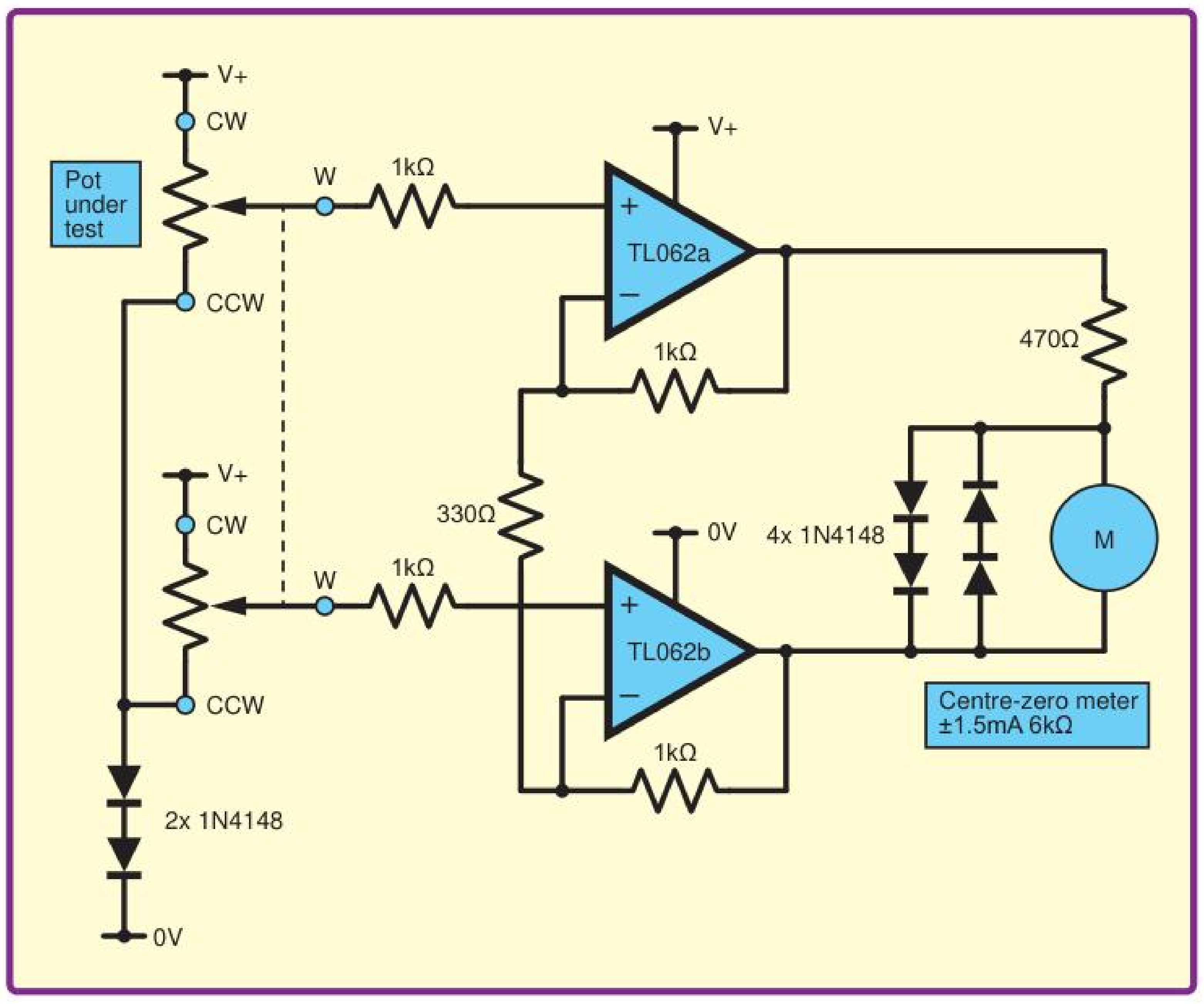

V+
CW
Pot under test
CCW
W
1kΩ
V+
TL062a
1kΩ
470Ω
V+
CW
W
1kΩ
330Ω
0V
4x 1N4148
M
TL062b
CCW
1kΩ
Centre-zero meter ±1.5mA 6kΩ
2x 1N4148
0V

Fig.49. More sophisticated dual pot test jig. Measure the difference between the tracks

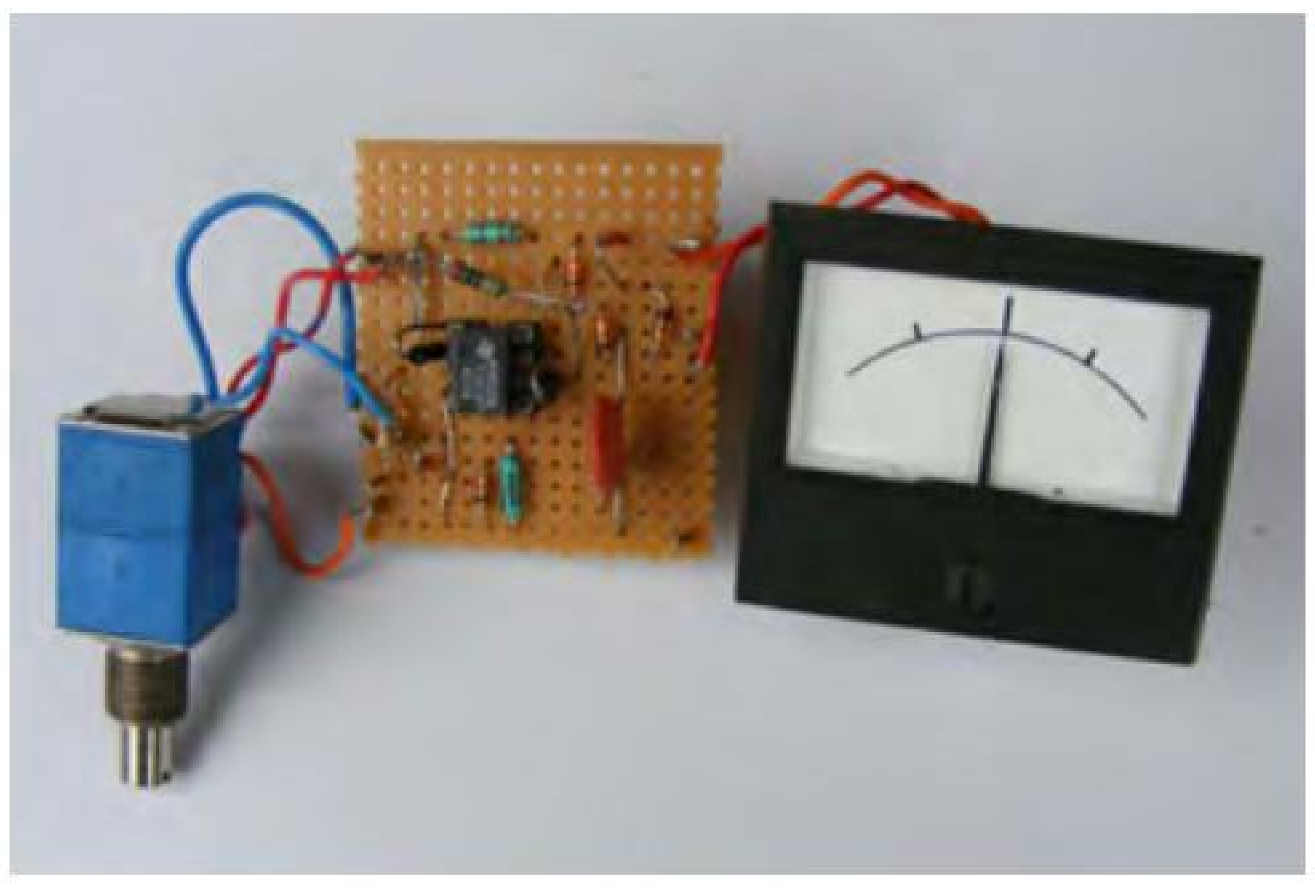


Fig.50. Practical realisation of dual pot tester

Active volume controls

A problem with all passive volume controls is that old overload/noise conundrum, the bane of all audio engineers. If you put the volume control after the pre-amp stage, it could overload with high inputs. If the volume control is placed before the pre-amp, there will be a noise problem, full hiss from the pre-amp and amplification of any noise from the pot. (See Fig.51) When I have this dilemma and have to choose, I say one can hear through hiss, but not distortion. There is a way round it, and that is to apply only the gain needed, by putting the volume control in a feedback network. I'll discuss active gain controls next month in the final part of this series

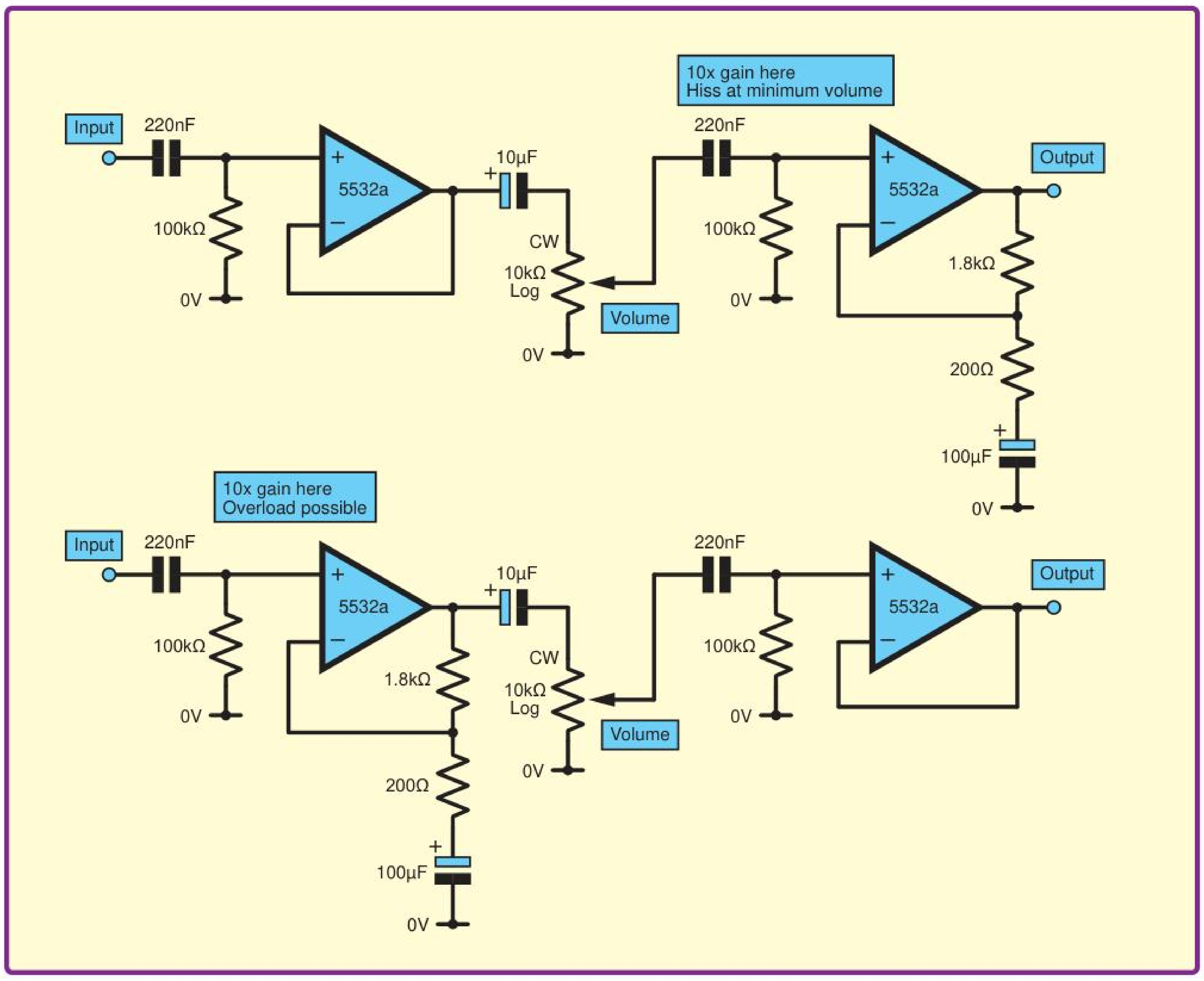

10x gain here
Hiss at minimum volume
Input
220nF
100kΩ
0V
5532a
10µF
CW
10kΩ Log
Volume
0V
220nF
100kΩ
0V
5532a
Output
1.8kΩ
200Ω
100µF
0V
10x gain here
Overload possible
Input
220nF
100kΩ
0V
5532a
1.8kΩ
200Ω
100µF
0V
10µF
CW
10kΩ Log
Volume
0V
220nF
100kΩ
0V
5532a
Output

Fig.51. Placing gain before volume control causes loss of headroom. Placing the gain afterwards can cause hiss

Fig.48. Pot track matching test jig – the pot plugs in quickly for batch testing

Max's Hot Beans

By Max The Magnificent

Good Grief! Is that the time?

OK, let us briefly set the stage before we plunge head-first into the heart of this column with gusto and abandon. As I discussed in my previous column, I'm in a competition to create a capriciously cunning chronograph using rings of tri-coloured LEDs (see *Max's Cool Beans*, *EPE*, January 2016). The idea is to implement the most intuitive interface using colour and other effects such that a casual observer immediately says: (a) 'That is a clock,' and (b) 'The time is…'

Additional points are to be awarded for enhanced display modes and functions. For example, my chum Steve Manley has come up with a really clever way to present a calendar function reflecting the day, month, and year. I'm going to unashamedly copy this (we're trading our code), but I'm also going to add a lunar calendar mode that reflects the current phase of the moon.

As seen in Fig.1, my carpenter chum Bob has created the most amazing cabinet with a hand-carved Celtic knot for me, and I've augmented my clock with the same audio spectrum analyser card that I used in my *Bodacious Acoustic Diagnostic Astoundingly Superior Spectromatic* (*BADASS*) display (**http://bit.ly/1I5ncTc**), plus I'm planning on adding a 9-DOF (nine degrees of freedom) MEM sensor that will allow me to do things like use my cunning chronograph as a compass. But I digress...

The painful part of prototyping

Once you finally have everything up and running (ticking away, as it were) just the way you want it, life is sweet. Problems arise, however, when you are in the prototyping phase and you want to experiment with different effects. Take my music mode, for example, in which I assign different frequency bands from the spectrum analyser to groups of pixels on the display.

In my case, I assigned three bands to the 60-element outer ring and two bands each to the 24-element and 12-element inner rings. Focusing on the outer ring, I assigned the colour red to the bass (63Hz) frequency and then associated this with four groups of five pixels at the north (N), south (S), east (E), and west (W) positions. Similarly, I assigned the colour blue to the next-but-one frequency (400Hz) and associated this with four groups of five pixels at the NW, NE, SW and SE positions. Finally, I assigned the colour purple to the 160Hz frequency, and associated this with eight groups of three pixels interspaced between the five-pixel groups. (I should point out that Steve Manley has also implemented a sound function, but he went in a completely different direction with regard to displaying his audio data – the funny thing is that we are both really impressed with the other's presentations.)

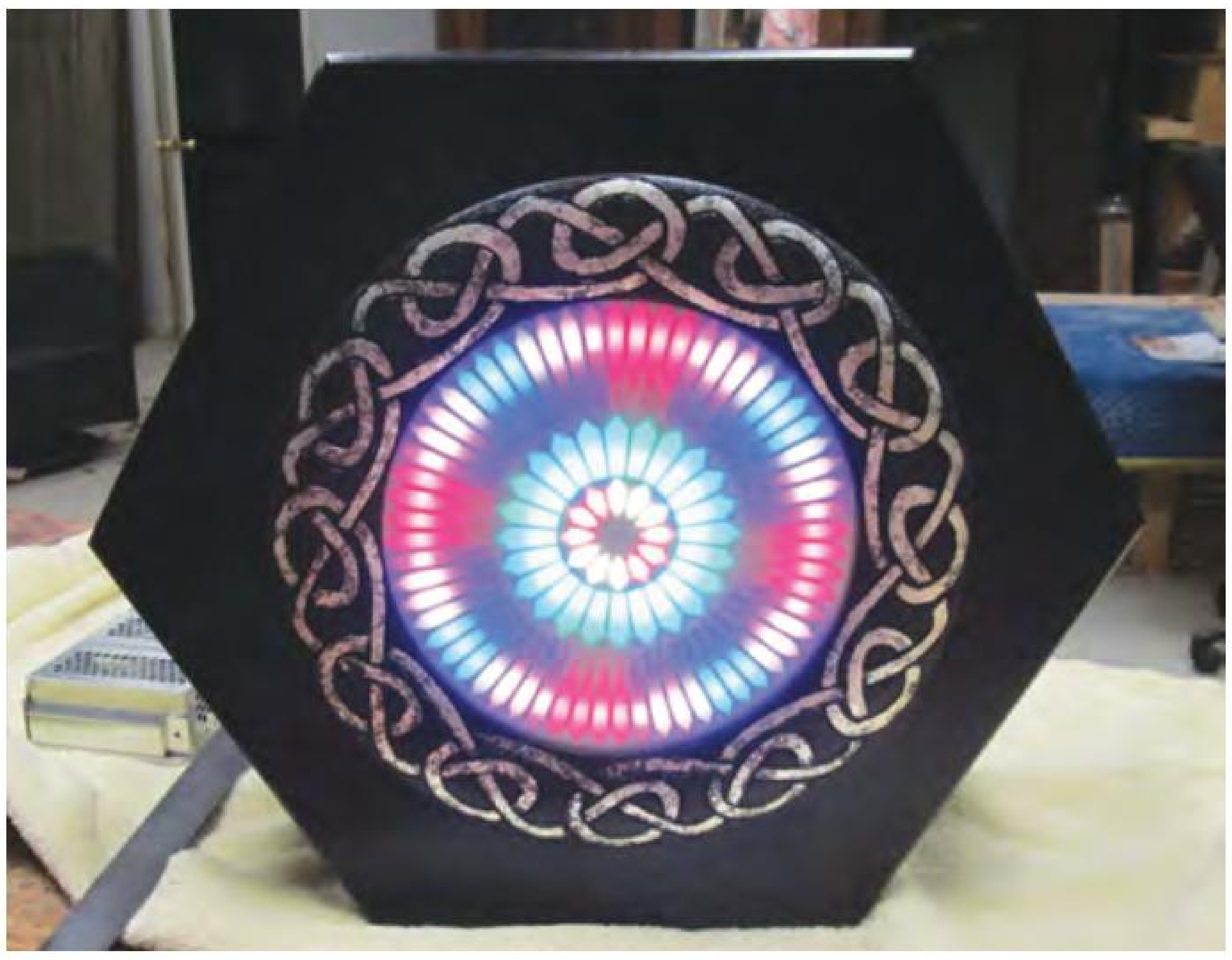


Fig.1. My cunning chronograph in music display mode

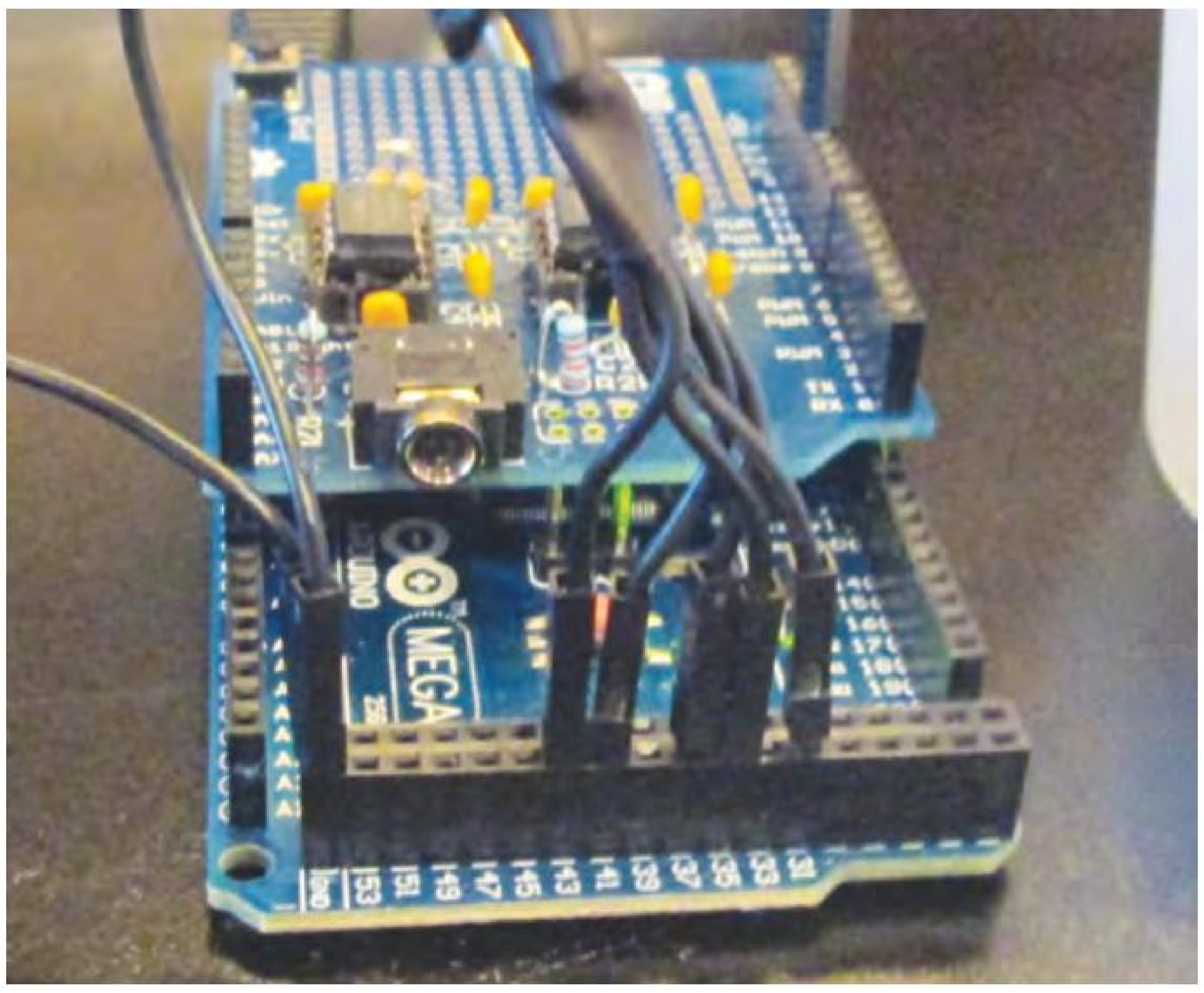


Fig.2. Using flying leads to define different states

In my case, I want to experiment with keeping all of the pixels in fixed locations (`Rotation = false`) or allowing the groups of pixels to gradually rotate (`Rotation = true`). If the rings are rotating, I want to experiment with them all rotating in the same direction (clockwise or anticlockwise) or have two rotating in one direction and the third rotating the other way.

The smallest number into which 60, 24, and 12 will divide without a remainder is 120. If we have a counter with 120 states, then we can arrange for the 60-element ring to perform a single revolution for each 120 count. We can also arrange for the 24-element and 12-element rings to each perform a single revolution for each 120 count (`RotationLock = true`); alternatively, for each rotation of the 60-element ring, we could let the 24-element ring perform five rotations and the 12-element ring perform 10 rotations (`RotationLock = false`). In this latter case, the 24- and 12-element rings would transition from one state to another in a rather clunky fashion (`Antialiasing = false`). These transitions could be made smoother by gradually fading from one colour to another (`Antialiasing = true`).

The bottom line is that we want to be able to quickly and easily experiment with different modes to see what they look like and decide which we like the best. How are we going to do this? Well, one way would be to define the current state in the code, recompile it, and upload it into the Arduino microcontroller (MCU), but this approach is certainly not 'quick' or 'easy.' Another approach is to assign a bunch of MCU pins to the various modes, to declare these as being of type INPUT_PULLUP (so they will be logic 1/high if they aren't connected to anything), and to then pull them down to 0V (logic 0/low) as required using flying leads. This was my first-pass solution, see Fig.2.

This is a lot better than having to recompile the code every time you want to try a different combination of effects, but it's still a pain having to run around to the back of the cunning chronograph, insert or remove a flying lead, and then race back to the front of the device to see what things look like under this new regime.

Ideally, it would be nice to be able to control things using a smartphone or a tablet computer. (In my case, it would have to be a tablet, because I no longer carry a mobile phone. About two years ago I came to the conclusion that no one ever called me with a message I actually wanted to hear!). But how are we to do this? The solution is a little rascal called a 'Simblee'.

Simblee marvelous, my dear!

I first mentioned the Simblee a couple of months ago when it was poised to leap onto the stage (see *Max's Hot Beans*, *EPE*, November 2015). The Simblee comprises a 32-bit ARM Cortex-M0 processor coupled with a Bluetooth Low Energy (BLE) sub-system, all presented in a small chip/package about 7mm × 10mm × 2mm. Commercial and industrial users would mount this chip directly in their systems. For the rest of us, there are two breakout boards – one with seven GPIOs (general-purpose input/outputs) and one with 29 GPIOs as illustrated in Fig 3.

The Simblee chip itself is the small package shown in the upper right-hand corner of each breakout board. For my purposes, I'm using the 29-GPIO version. In order to program the Simblee, you also need a small USB shield (not shown here).

The Simblee itself is Arduino compatible. All you have to do is download the Simblee library and include the Simblee as an option in the Arduino's board manager (all of this is described in the Simblee documentation).

I'll be discussing the nitty-gritty details in a future column. For the moment, let's just remind ourselves that a basic Arduino program includes two core functions: `setup()` and `loop()`. A Simblee program adds two more core functions: `ui()`, which describes the user interface (UI), and `event()`, which is where any changes in the user interface are communicated back to the main sketch.

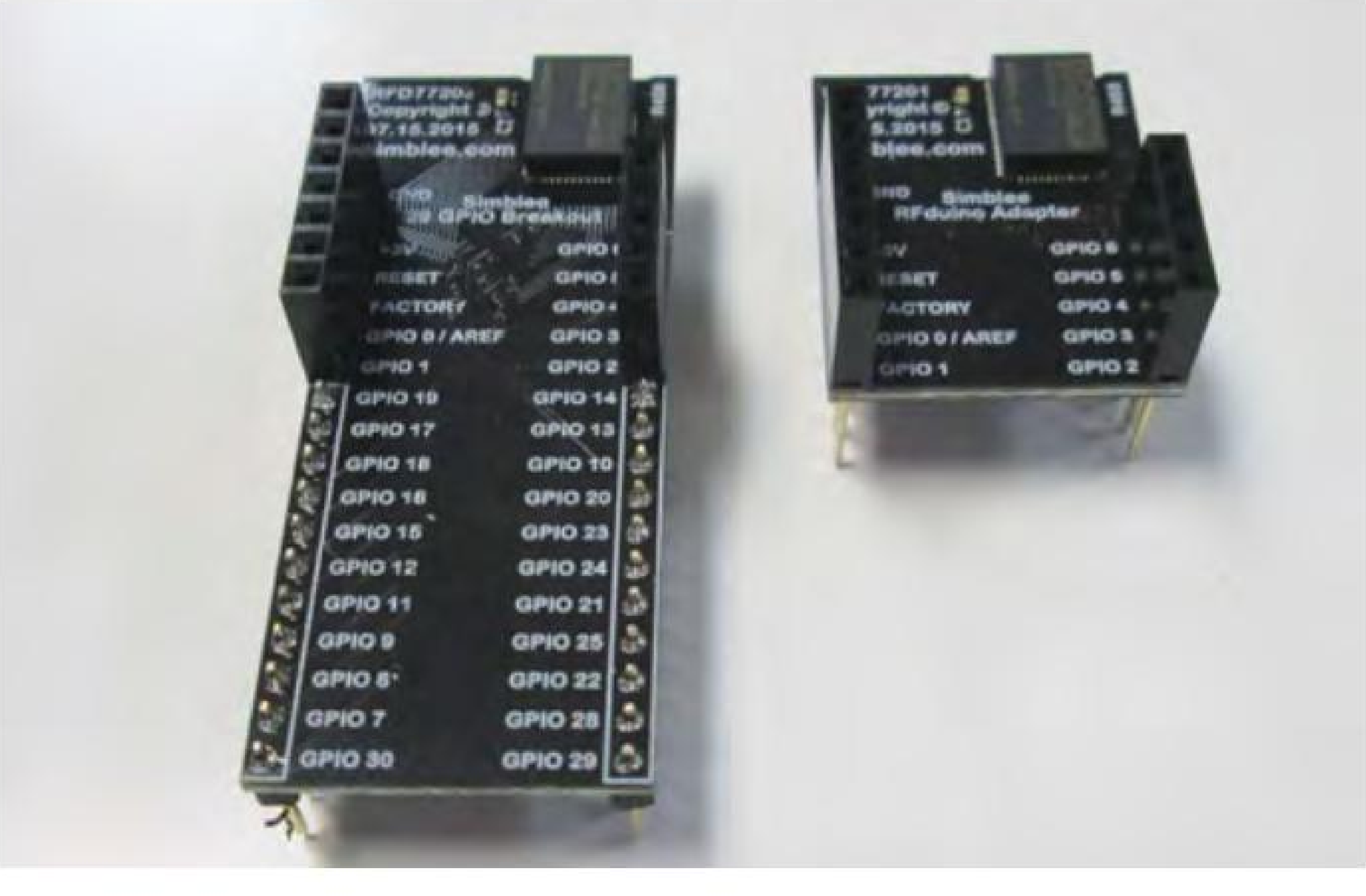


Fig.3. Simblee breakout boards: 29 GPIO (left) and 7 GPIO (right) – the boards are roughly 25mm wide

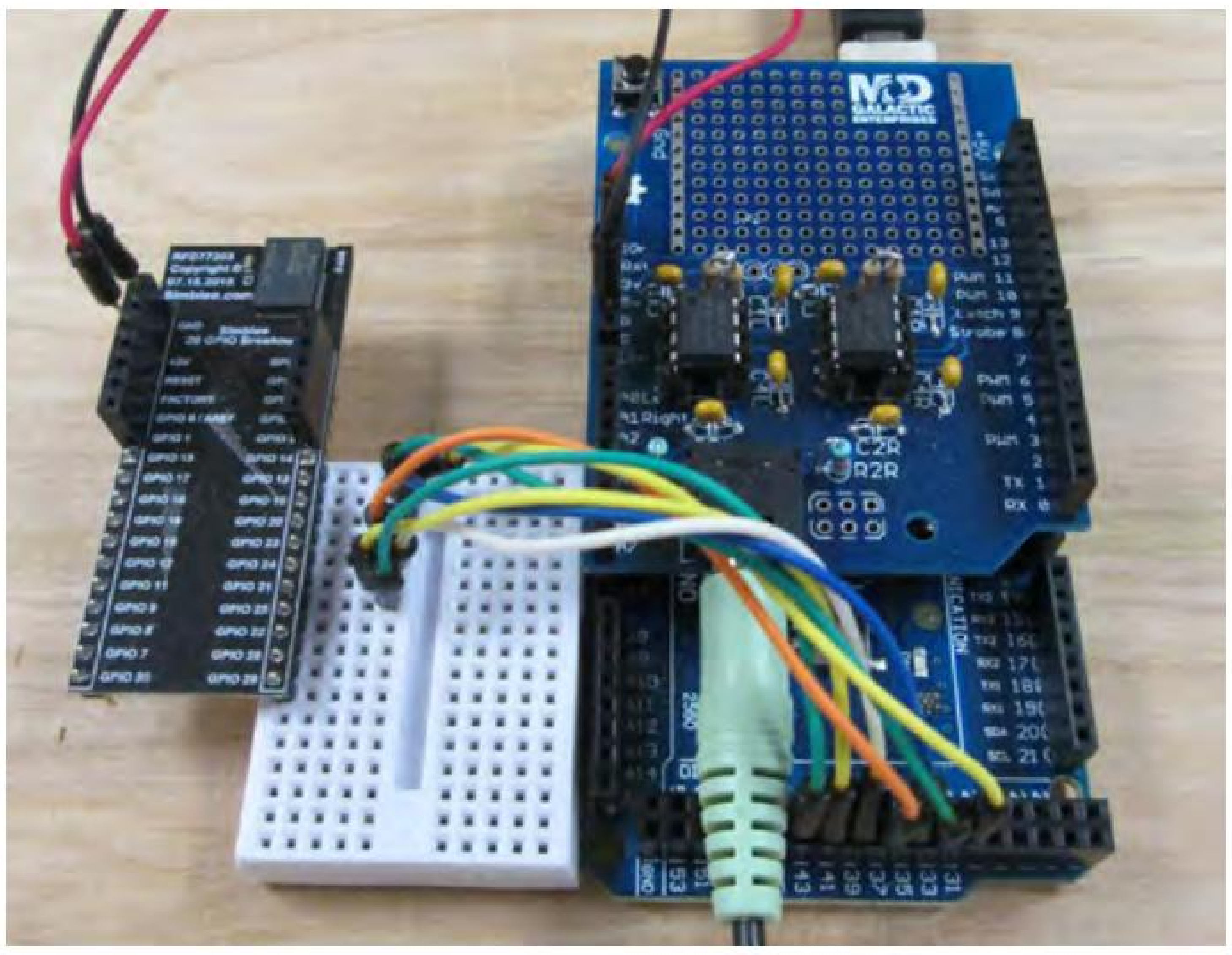


Fig.4. Using a Simblee to define different states

In the case of the `ui()` function, this is where you say things like 'I want to have a switch at location XY.' All of this is done using function calls to the Simblee library. Once you've captured your sketch, including the user interface, you upload it into the Simblee.

Now comes the clever part. You download a free Simblee app onto your iOS or Android smartphone or tablet. When you launch this app, it 'pings' the surrounding area saying, 'Are there any Simblees out there?' Each Simblee module responds by saying, 'Yes, I'm here; my name is XYZ and I do xxxx.' You are presented with a list of these Simblees on your screen. When you tap one, the Simblee app calls out to the selected Simblee saying 'You're up,' and that Simblee responds by uploading its UI, which is then rendered on your screen.

At this point, you can use your smartphone or tablet to control the selected Simblee module. Again, I'll be talking about this in more detail in future columns. For the moment, let's just note that most people will probably use the MCU in the Simblee to directly interface with the outside world to monitor and control things.

In my case, however, I've already got everything running on my Arduino, plus I need the Arduino to run Adafruit's NeoPixel library whose timing is critical. Thus, as seen in Fig.4, I've connected my Simblee into a breadboard and I'm using it to drive logic 0 and 1 values into the Arduino pins I'm using to control my various effects.

The bottom line is that I've replaced the flying leads shown in Fig.2 with a Simblee. This means that I can now sit in a comfy chair in front of my cunning chronograph and look at a graphical user interface on my iPad showing a set of switches marked 'Rotation,' 'Rotation-Lock,' 'Antialiasing,' and so forth. All I have to do is casually drag a selected switch with my finger to turn it on/off. This is immediately transmitted to my Simblee, which modifies the corresponding pin, which is seen and acted on by the Arduino.

Steve Manley is also using a Simblee to replicate the functionality of the two buttons on the back of his cunning chronograph (I'll be talking more about this in a future column also). It's a lot easier to wrap your brain around this if you can see it in action, so I just posted a short video (**http://bit.ly/1TgPf69**). Until next time, have a good one!

Any comments or questions? – please feel free to send me an email at: **max@CliveMaxfield.com**

EPE IS PLEASED TO BE ABLE TO OFFER YOU THESE

ELECTRONICS CD-ROMS

From £49.00

FEATURED IN OUR TEACH-IN 2015 SERIES

TINA Design Suite V10

Analogue, Digital, Symbolic, RF, MCU and Mixed-Mode Circuit Simulation and PCB Design with TINA

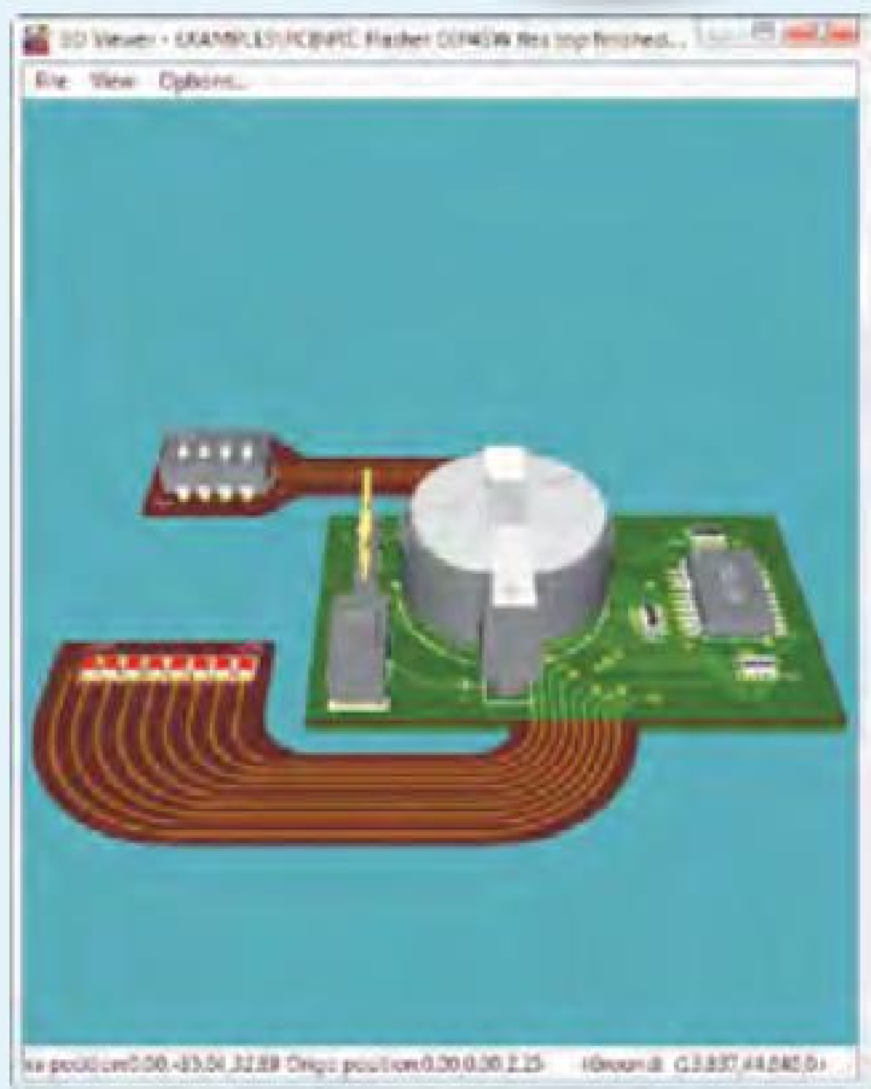
TINA Design Suite V10 is a powerful yet affordable software package for analysing, designing and real time testing analogue, digital, MCU, and mixed electronic circuits and their PCB layouts. You can also analyse RF, communication, optoelectronic circuits, test and debug microcontroller applications.

Enter and analyse any circuit up to 100 nodes (student), or 200 with the Basic (Hobbyist) version within minutes with TINA's easy-to-use schematic editor. Enhance your schematics by adding text and graphics. Choose components from the large library containing more than 10,000 manufacturer models. Analyse your circuit through more than 20 different analysis modes or with 10 high tech virtual instruments.

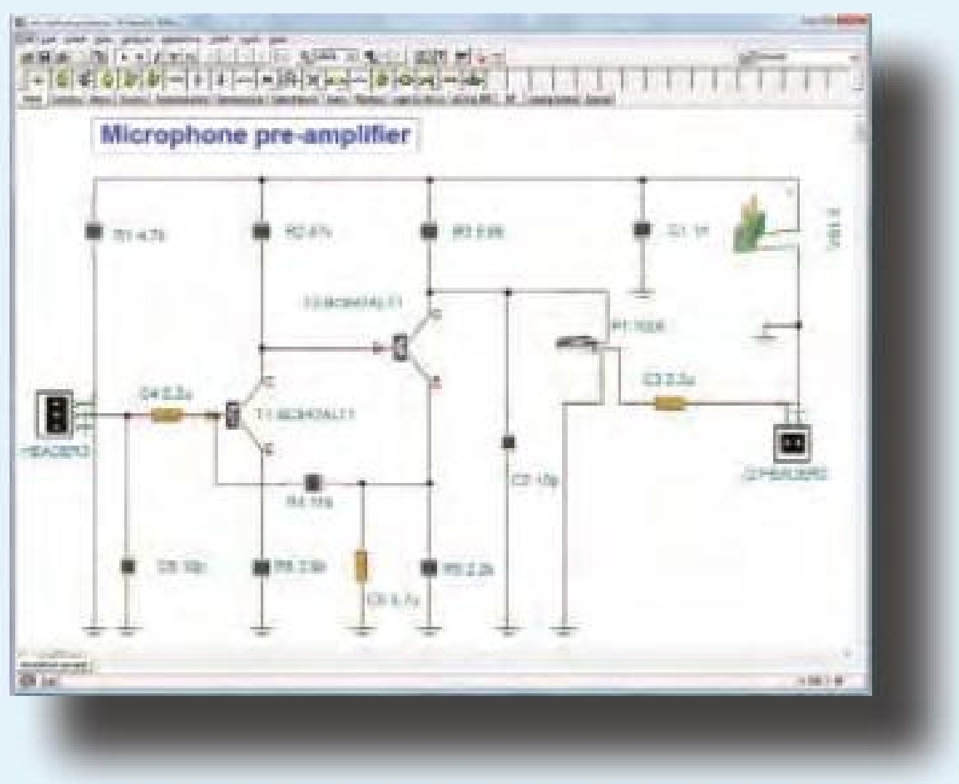
Present your results in TINA's sophisticated diagram windows, on virtual instruments, or in the live interactive mode where you can even edit your circuit during operation.

Customise presentations using TINA's advanced drawing tools to control text, fonts, axes, line width, colour and layout. You can create and print documents directly inside TINA or cut and paste your results into your favourite word procesing or DTP package.

TINA includes the following Virtual Instruments: Oscilloscope, Function Generator, Multimeter, Signal Analyser/Bode Plotter, Network Analyser, Spectrum Analyser, Logic Analyser, Digital Signal Generator, XY Recorder.



This offer gives you a CD-ROM – the software will need registering (FREE) with Designsoft (TINA), details are given within the package.



Get TINA Basic V10 (Hobbyist) for £129 or Student V10 version for £49

Prices include VAT and UK postage

+ get a 1 year free subscription for TINACloud the breakthrough cloud version of TINA which you can run on most operating systems and computers, including PCs, Macs, thin clients iPads and other tablets – even on many smart phones, smart TVs and e-book readers.

To order please either fill out and return the order form, or call us on 01202 880299

Alternatively you can order via our secure online shop at: www.epemag.com

ELECTRONICS TEACH-IN 2

ELECTRONICS TEACH-IN 2 CD-ROM
USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers. An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

CD-ROM **Order code ETI2 CD-ROM** **£9.50**

ELECTRONICS TEACH-IN 3

ELECTRONICS TEACH-IN 3 CD-ROM

The three sections of this CD-ROM cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on circuit design problems – from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered. Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 circuit designs submitted by the readers of *EPE*.

The CD-ROM also contains the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial).

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC.

CD-ROM **Order code ETI3 CD-ROM** **£8.50**

ELECTRONICS TEACH-IN 4

ELECTRONICS TEACH-IN 4 CD-ROM

A Broad-Based Introduction to Electronics.

The Teach-In 4 CD-ROM covers three of the most important electronics units that are currently studied in many schools and colleges. These include, Edexcel BTEC level 2 awards and the electronics units of the new Diploma in Engineering, Level 2.

The CD-ROM also contains the full Modern Electronics Manual, worth £29.95. The Manual contains over 800 pages of electronics theory, projects, data, assembly instructions and web links.

A package of exceptional value that will appeal to all those interested in learning about electronics or brushing up on their theory, be they hobbyists, students or professionals.

CD-ROM **Order code ETI4 CD-ROM** **£8.99**

ELECTRONICS TEACH-IN 4
A BROAD-BASED INTRODUCTION TO ELECTRONICS
THE MODERN ELECTRONICS MANUAL
BASE MANUAL
ELECTRONICS TEACH-IN 3
CIRCUIT SURGERY
PRACTICALLY SPEAKING
INGENUITY UNLIMITED

ELECTRONICS TEACH-IN BUNDLE – SPECIAL BUNDLE PRICE £14 FOR PARTS 1, 2 & 3

CD-ROMs **Order code ETIBUNDLE** Bundle Price **£14.00**

PICmicro TUTORIALS AND PROGRAMMING

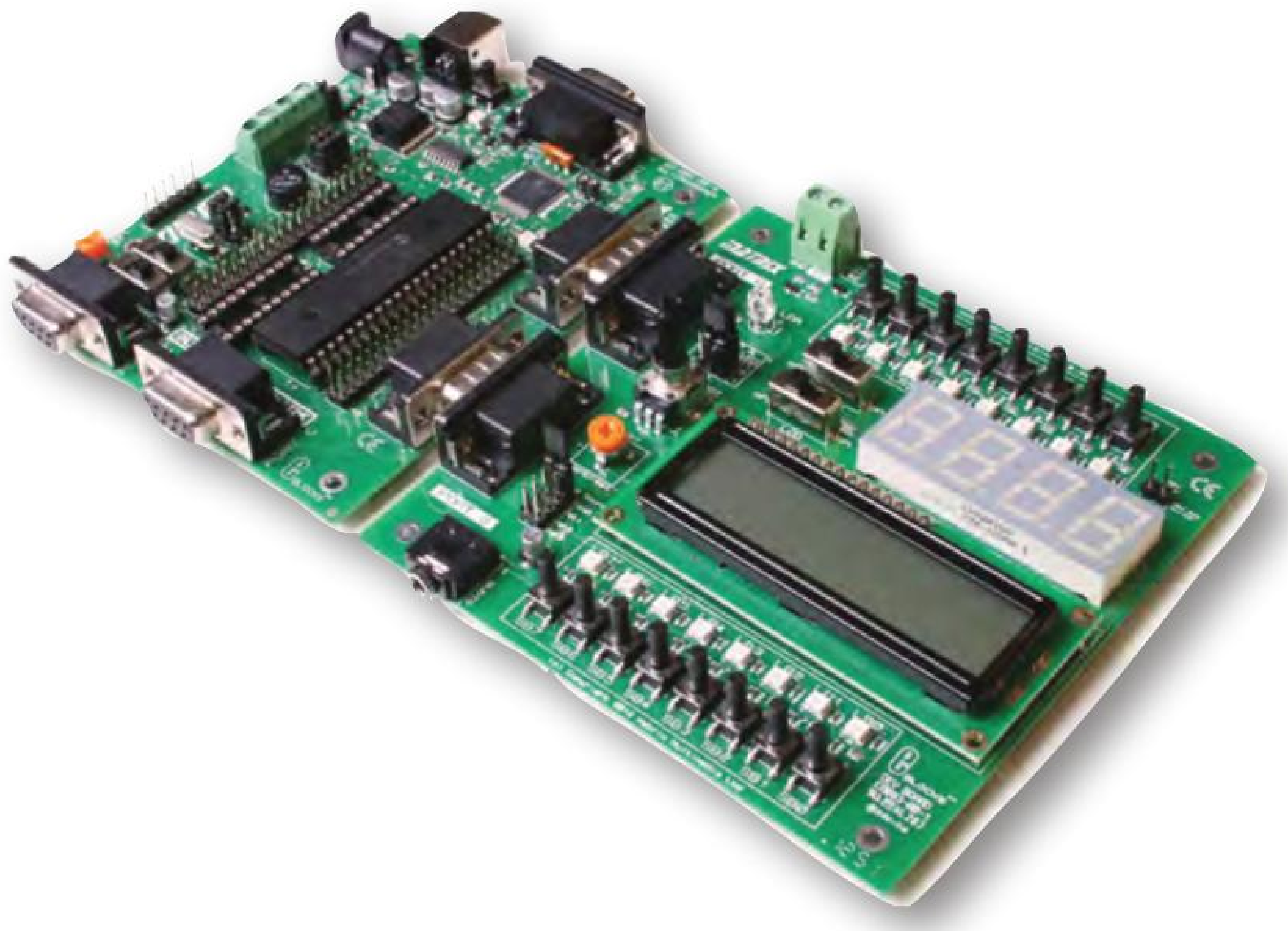
HARDWARE

PICmicro Multiprogrammer Board and Development Board

Suitable for use with the three software packages listed below

This flexible PICmicro microcontroller programmer board and combination board allows students and professional engineers to learn how to program PICmicro microcontrollers as well as program a range of 8, 18, 28 and 40 pin devices from the 12, 16 and 18 series PICmicro ranges. For experienced programmers all programming software is included in the MLoader utility that is free to download when you buy the multiprogrammer board. For those who want to learn, choose one or all of the packages below to use with the hardware.

- Makes it easier to develop PICmicro projects
- Supports low cost Flash-programmable PICmicro devices
- Fully featured integrated displays – 16 individual LEDs, quad 7-segment display and alphanumeric LCD display
- Supports PICmicro microcontrollers with A/D converters
- Fully protected expansion bus for project work
- USB programmable
- Compatible with the E-blocks range of accessories



£167 including VAT and postage, supplied with USB cable and free to download programming software

SOFTWARE

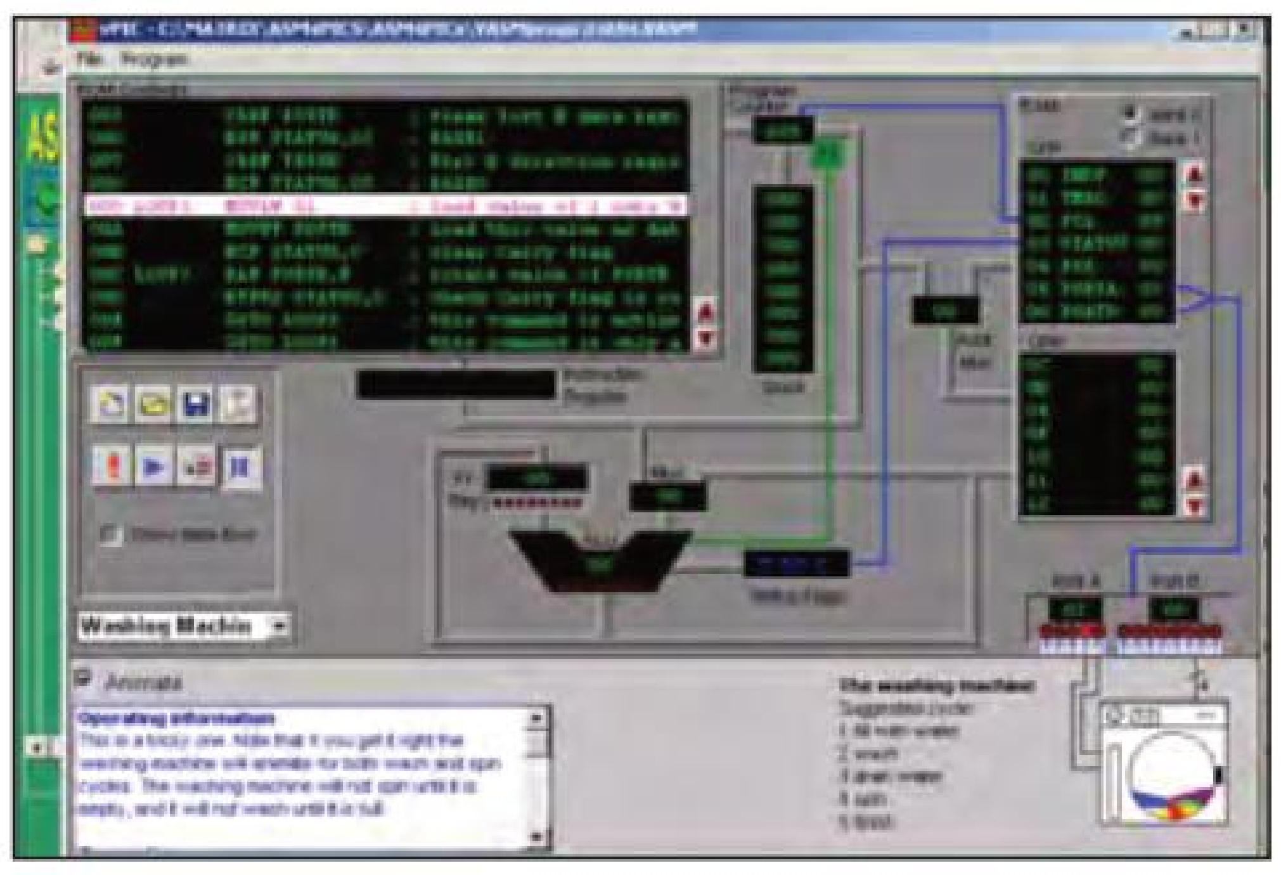
ASSEMBLY FOR PICmicro V5

(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

• Comprehensive instruction through 45 tutorial sections • Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator • Tests, exercises and projects covering a wide range of PICmicro MCU applications • Includes MPLAB assembler • Visual representation of a PICmicro showing architecture and functions • Expert system for code entry helps first time users • Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) • Imports MPASM files.

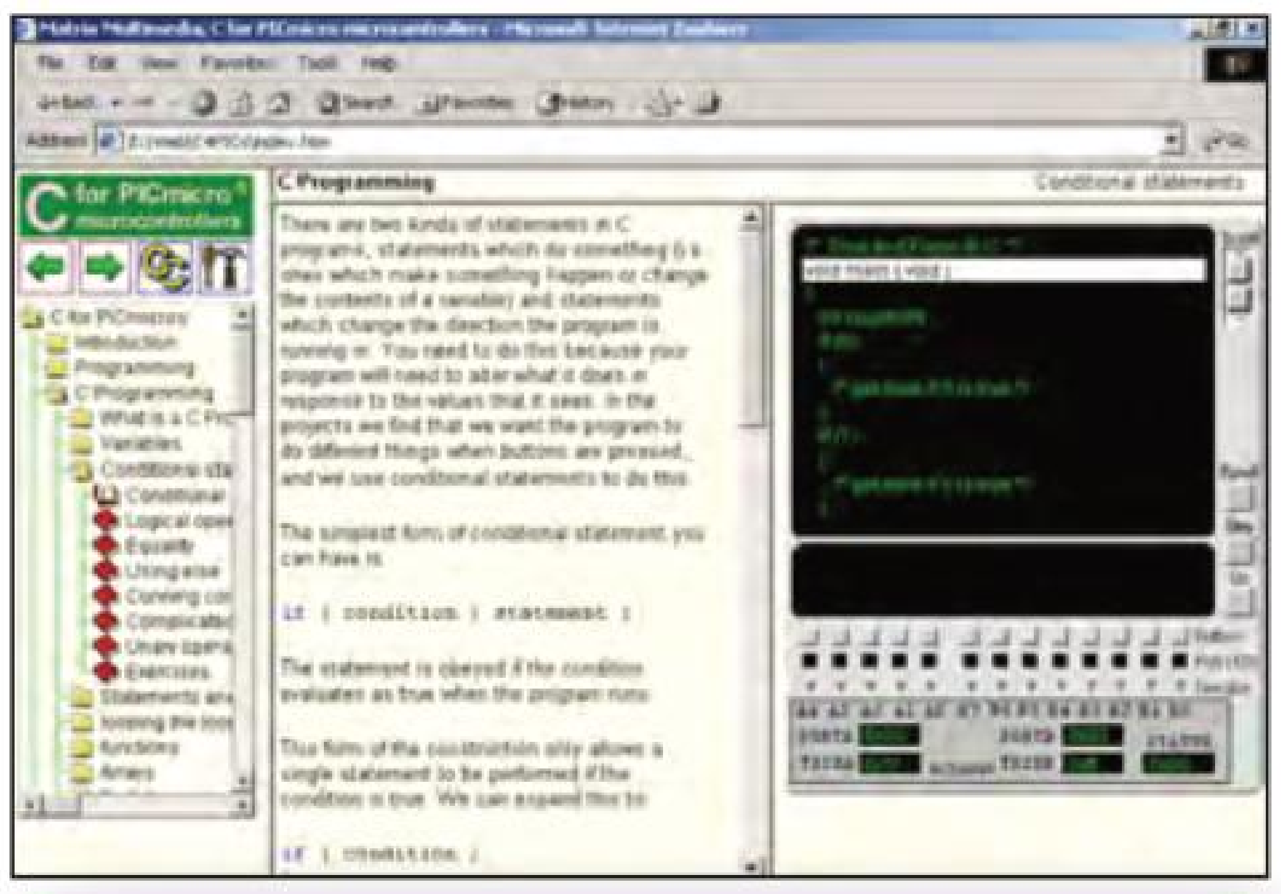


'C' FOR 16 Series PICmicro Version 5

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

• Complete course in C as well as C programming for PICmicro microcontrollers • Highly interactive course • Virtual C PICmicro improves understanding • Includes a C compiler for a wide range of PICmicro devices • Includes full Integrated Development Environment • Includes MPLAB software • Compatible with most PICmicro programmers • Includes a compiler for all the PICmicro devices.



Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V6

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

Please note: Due to popular demand, Flowcode PICmicro, AVR, DSPIC, PIC24 & ARM V6 are now available as a download. Please include your email address and a username (of your choice) on your order. A unique download code will then be emailed to you. If you require the CDROM as a back-up then please add an extra £14 to the price.

PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

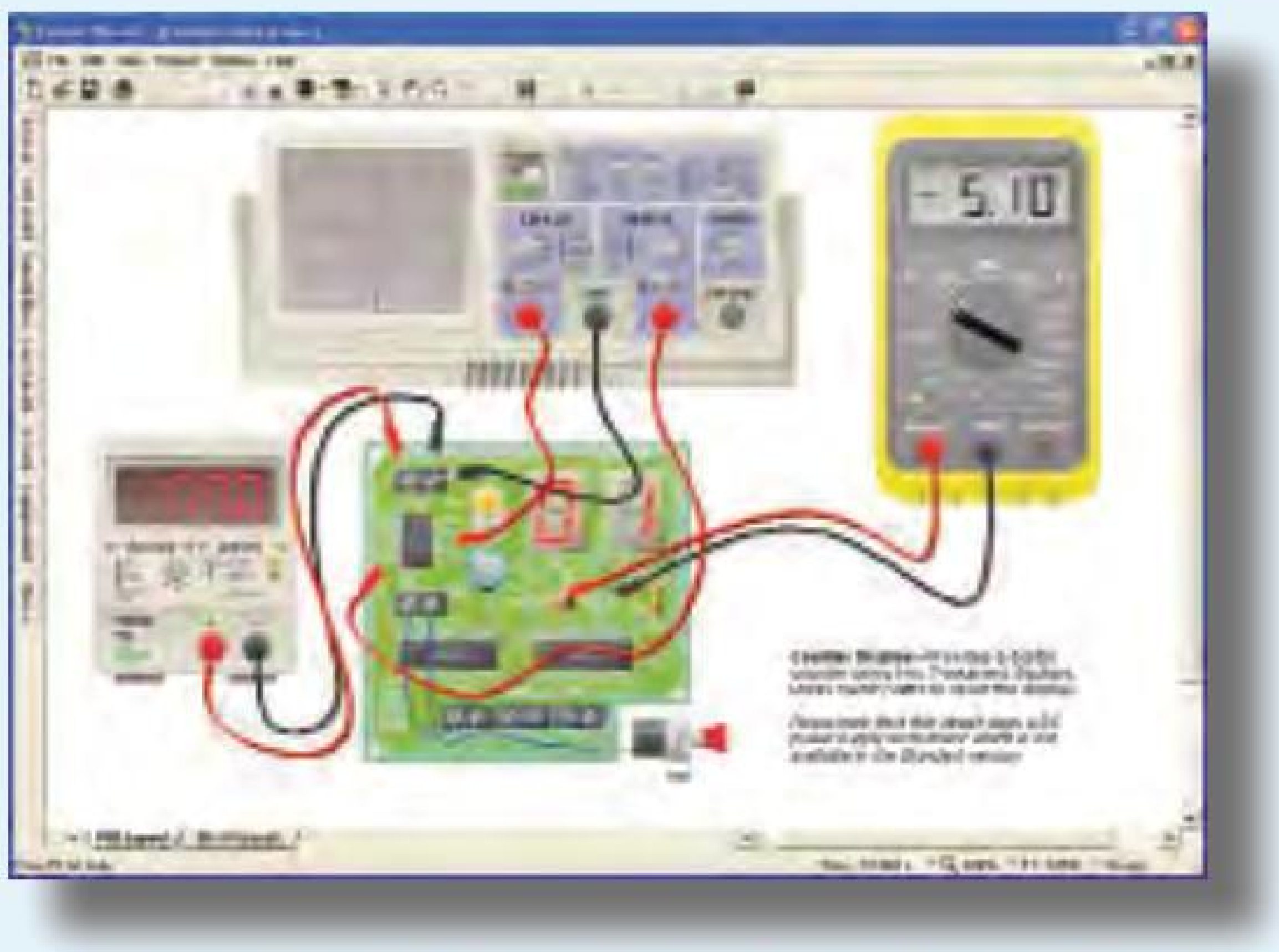
Hobbyist/Student	**£58.80**	**inc VAT**
Professional (Schools/HE/FE/Industry)	**£150**	**plus VAT**
Professional 10 user (Network Licence)	**£499**	**plus VAT**
Site Licence	**£999**	**plus VAT**
Flowcode (choose PIC, AVR, ARM, dsPIC, PIC24)	**£94.80**	**plus VAT**

CIRCUIT WIZARD

Circuit Wizard is a revolutionary software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package.
Two versions are available, Standard or Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

** Circuit diagram design with component library (500 components Standard, 1500 components Professional) * Virtual instruments (4 Standard, 7 professional) * On-screen animation * Interactive circuit diagram simulation * True analogue/digital simulation * Simulation of component destruction * PCB Layout * Interactive PCB layout simulation * Automatic PCB routing * Gerber export * Multi-level zoom (25% to 1000%) * Multiple undo and redo * Copy and paste to other software * Multiple document support*



This software can be used with the *Jump Start* and *Teach-In 2011* series (and the *Teach-In 4* book).

Standard **£61.25** inc. VAT. Professional **£75** plus VAT.

GCSE ELECTRONICS

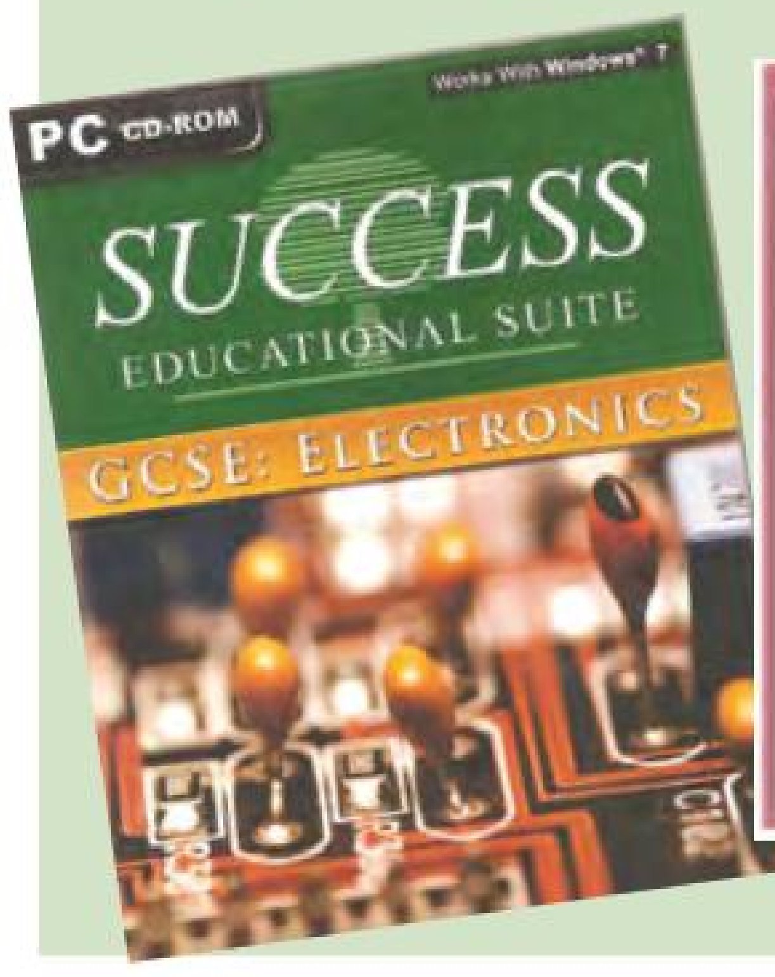
Suitable for any student who is serious about studying and who wants to achieve the best grade possible. Each program's clear, patient and structured delivery will aid understanding of electronics and assist in developing a confident approach to answering GCSE questions. The CD-ROM will be invaluable to anyone studying electronics, not just GCSE students.

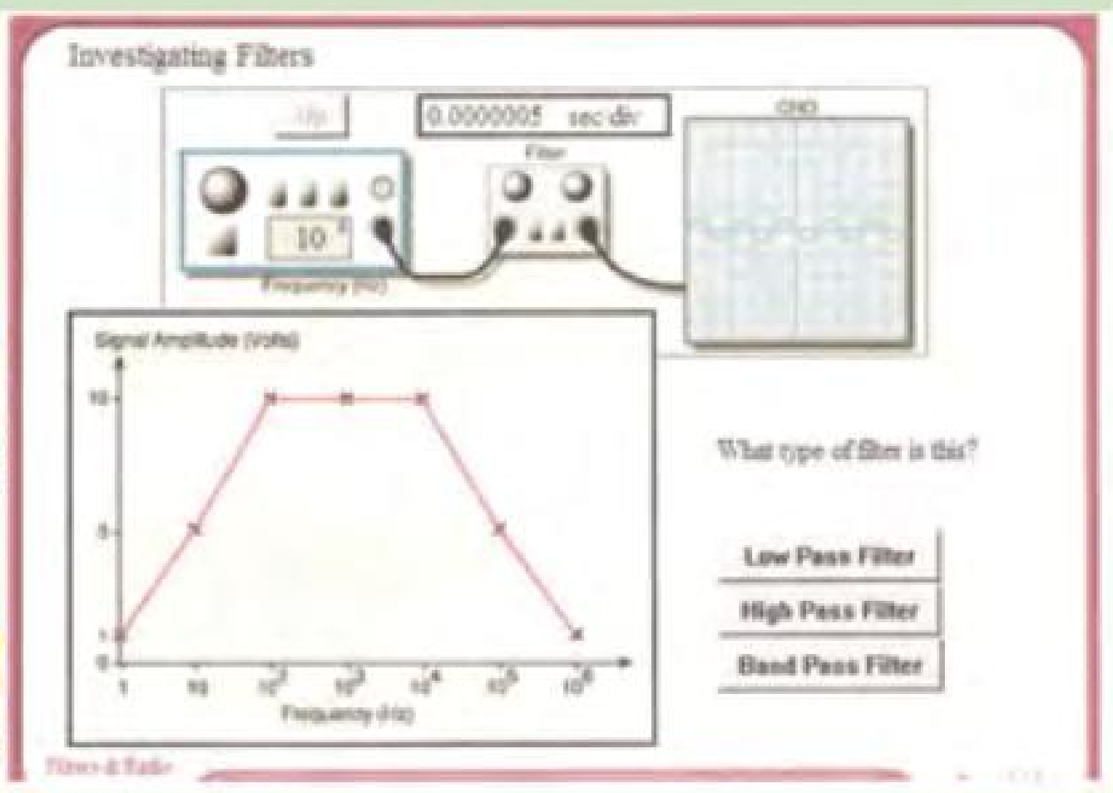
**** Contains comprehensive teaching material to cover the National Curriculum syllabus * Regular exercises reinforce the teaching points * Retains student interest with high quality animation and graphics * Stimulates learning through interactive exercises * Provides sample examination ques-tions with model solutions * Authored by practising teachers * Covers all UK examination board syllabuses * Caters for all levels of ability * Useful for self-tuition and revision***

SUBJECTS COVERED

Electric Circuits – Logic Gates – Capacitors & Inductors – Relays – Transistors – Electric Transducers – Operational Amplifiers – Radio Circuits – Test Instruments

Over 100 different sections under the above headings





£12.50 inc. VAT and P&P

Please send me: **CD-ROM ORDER FORM**

☐ **Assembly for PICmicro V5**
☐ **'C' for 16 Series PICmicro V5**

Version required:
☐ **Hobbyist/Student**
☐ **Professional**
☐ **Professional 10 user**
☐ **Site licence**

Note: The software on each version is the same, only the licence for use varies.

☐ **Flowcode for PICmicro V6 (DOWNLOAD ONLY)**
☐ **Flowcode for AVR V6 (DOWNLOAD ONLY)**
☐ **Flowcode for ARM V6 (DOWNLOAD ONLY)**
☐ **Flowcode for dsPIC V6 (DOWNLOAD ONLY)**
☐ **Flowcode for PIC24 V6 (DOWNLOAD ONLY)**

Email: . . . .

Username: . . . .

☐ **PICmicro Multiprogrammer Board and Development Board V4 (hardware)**

☐ **Circuit Wizard – Standard**
☐ **Circuit Wizard – Professional**
☐ **GCSE Electronics**

NEW ☐ **TINA Design Suite V10 Basic (Hobbyist)**
☐ **TINA Design Suite V10 (Student)**

☐ **Teach-In 2**
☐ **Teach-In 3**
☐ **Teach-In 4**
☐ **Teach-In Bundle**

Full name: . . . .

Address: . . . .

. . . . Post code: . . . . Tel. No: . . . .

Signature: . . . .

☐ I enclose cheque/PO in £ sterling payable to WIMBORNE PUBLISHING LTD for £ . . . .
☐ Please charge my Visa/Mastercard/Maestro: £ . . . .
Valid From: . . . . Card expiry date: . . . .
Card No: . . . . Maestro Issue No. . . . .
Card Security Code . . . . (The last 3 digits on or just under the signature strip)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

ORDERING
ALL PRICES INCLUDE UK POSTAGE

Standard/Student/Basic (Hobbyist) Version price includes postage to most countries in the world
EU residents outside the UK add £5 for airmail postage per order

Professional, Multiple User and Site License Versions – overseas readers add £5 to the basic price of each order for airmail postage (**do not add VAT** unless you live in an EU (European Union) country, then add VAT at 20% or provide your official VAT registration number).

Send your order to:
Direct Book Service
Wimborne Publishing Ltd
113 Lynwood Drive, Merley,
Wimborne, Dorset BH21 1UU

To order by phone ring

01202 880299. Fax: 01202 843233
Goods are normally sent within seven days

E-mail: orders@wimborne.co.uk
Online shop:
www.epemag.com

blueberry®

Add a blueberry to your Raspberry Pi

Turn your Raspberry Pi into a Multi-Purpose IoT Controller Board

The Blueberry IoT Controller for the Raspberry Pi is a versatile device designed to interact with the real world by reading sensors, controlling electrical equipment and using popular communication channels. It is supported by a range of other devices which can turn your Raspberry Pi into the nerve centre of a simple or complex monitoring and control system.

I2C 14 Segment LED Display Issue-G
Astilbe ©2015
WARNING ISOLATE FROM MAINS BEFORE SERVICING
IRM-15-5
ASTILBE ©2015
RADIO ISSUE-G

CONTROL

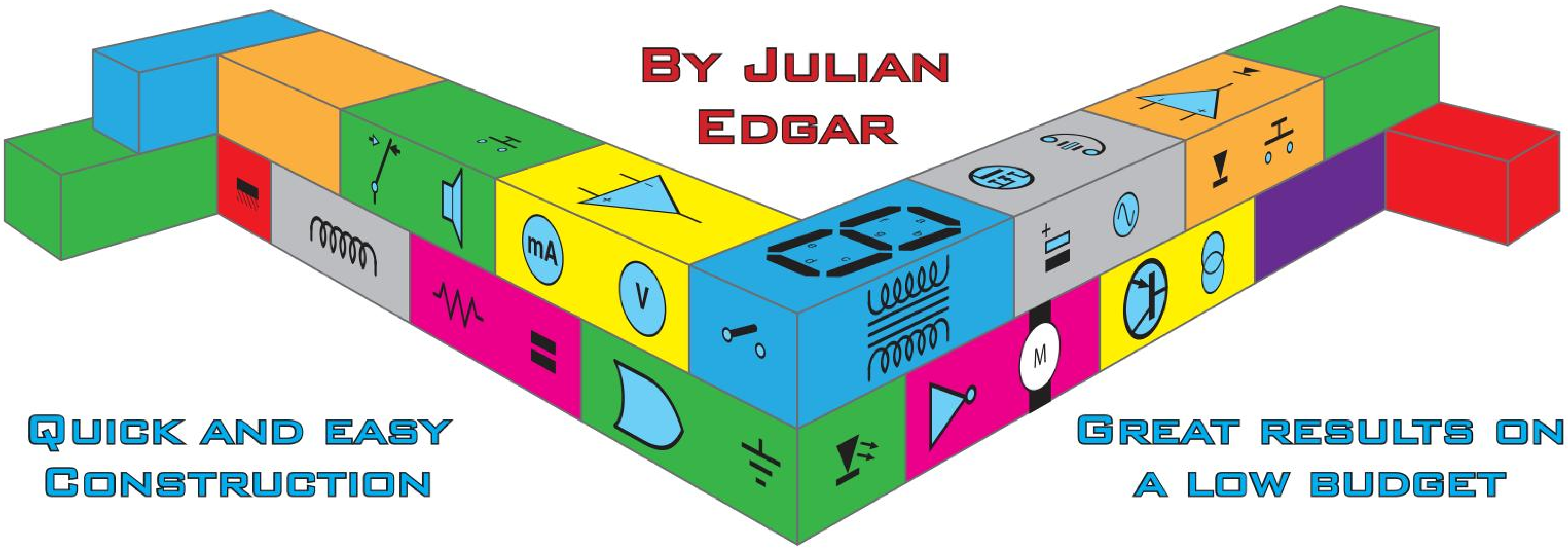
gates, garage doors, air-conditioning, irrigation systems and much more.

Use the power and connectivity of the Pi or the on-board GSM to control your system from anywhere in the world or receive reports and alerts via email or text (SMS).

Rapid electronics

For full details and pricing visit
www.rapidonline.com
Rapid Electronics part of the CONRAD Group

ELECTRONIC BUILDING BLOCKS



BY JULIAN EDGAR

QUICK AND EASY CONSTRUCTION

GREAT RESULTS ON A LOW BUDGET

PULSING TIMER MODULE

Large complex projects are fun, but they take time and can be expensive. Sometimes you just want a quick result at low cost. That's where this series of *Electronic Building Blocks* fits in. We use 'cheap as chips' components bought online to get you where you want to be... FAST! These projects range from around £15 to under a fiver... bargains!

Pulsing Timer Module

Here's a great electronic module that can be used to pulse an output. It is widely adjustable, with both the 'on' and 'off' times able to be set separately. It uses a relay output that is able to drive high-current loads (up to 10A). Finally, it's incredibly cheap – less than £5 delivered to your UK letterbox – see Fig.1.

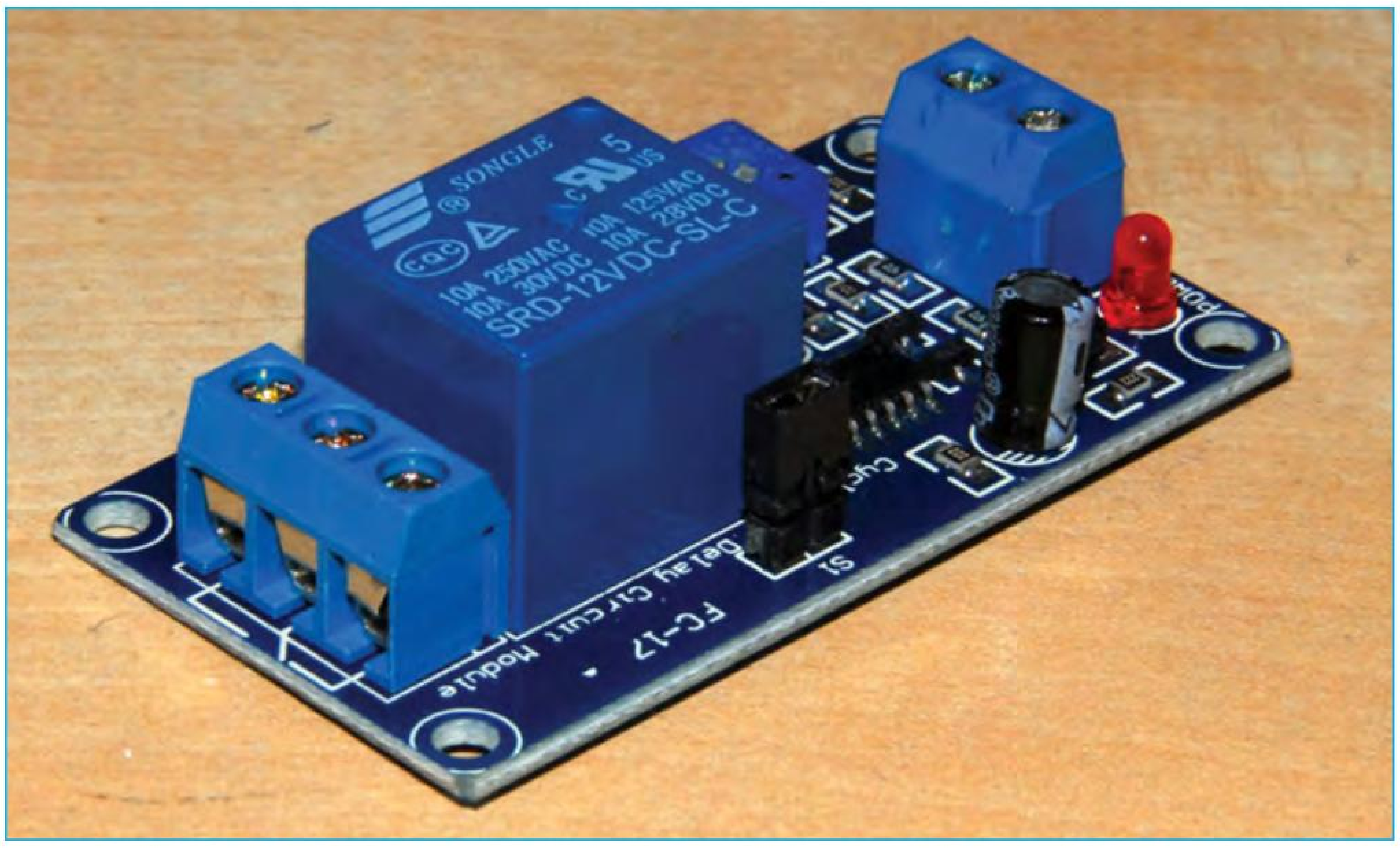
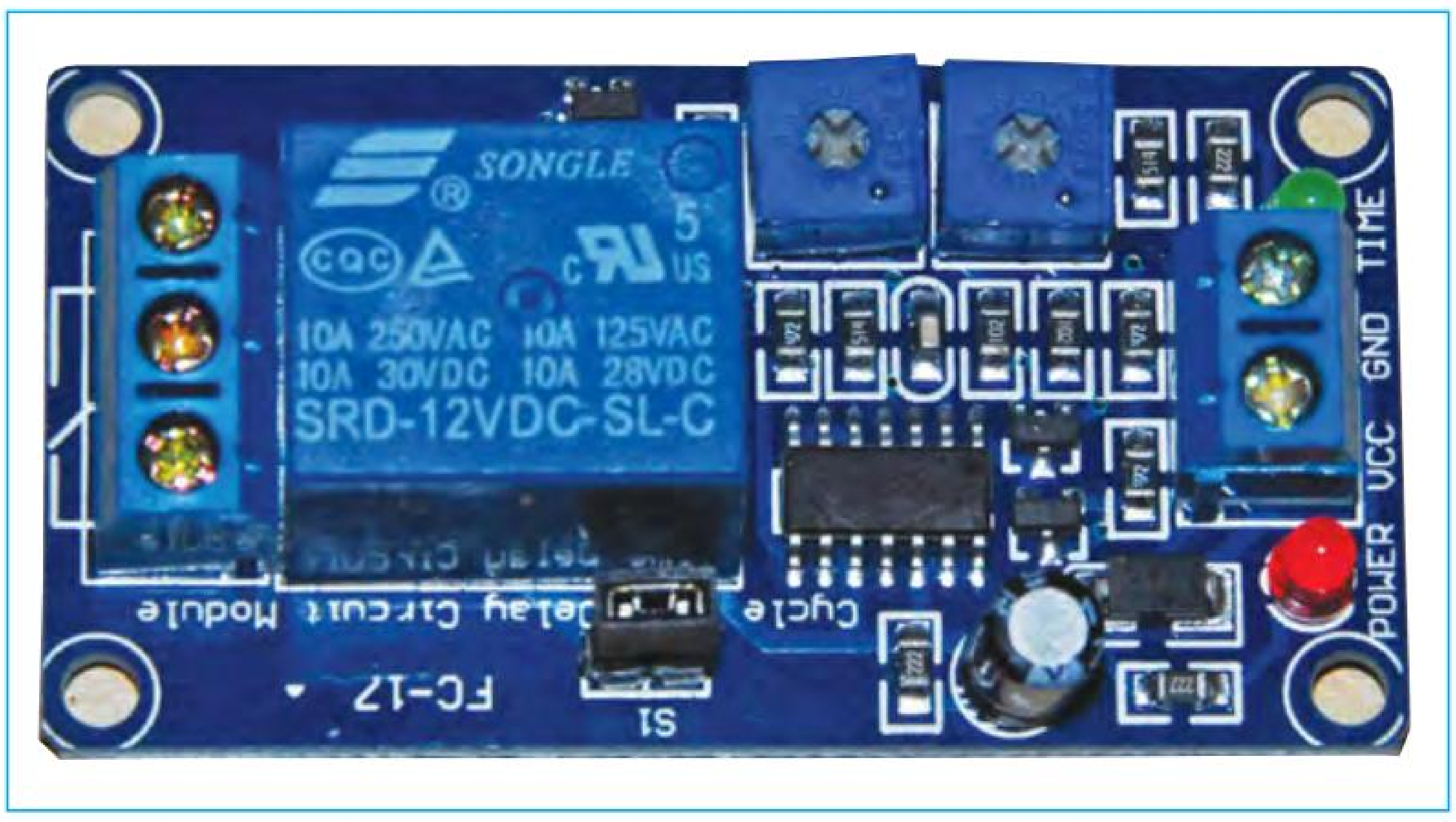


Fig.1. Fantastic value – a Pulsing Timer Module *for under £5*

The fully constructed module is about 56 × 30mm. At one end of the board it has inputs for power and ground, and the other end has three relay connections – one for common, one for normally open and the other for normally closed, as shown in Fig.2.

Pots and links

There are two pots mounted on the board – one controls the 'off' time and the other the 'on' time.



Pulsing Timer Module connections – common, normally open and closed on the left; power on the right

A red LED glows whenever power is applied, and a green LED turns on when the relay is activated.

There is also a configurable link on the board (see Fig.3). Placing the link on the board feeds 12V to the 'common' terminal of the relay. This makes wiring much simpler in many applications, because the load can be connected between the other relay terminal and ground (more on this in a moment).

The easiest way to see how this module works is to connect power and ground to the appropriate terminals. Rotate both pots fully anti-clockwise. Turn on power and the red LED will immediately light. With the pots set as described, the green LED will flash (and the relay) click, with the 'on' and 'off' times both being one second. This is the shortest output time available.

On/off times

Rotate the 'off' pot a fraction clockwise. The output will still be activated for one second but this might now occur only every five seconds. And if, for example, you wanted the output to be activated at five-second intervals for the longer period of 10 seconds, you'd turn the 'on' pot a little more clockwise.

You can see that both the frequency and duty cycle can be adjusted in this way. On the sample module,

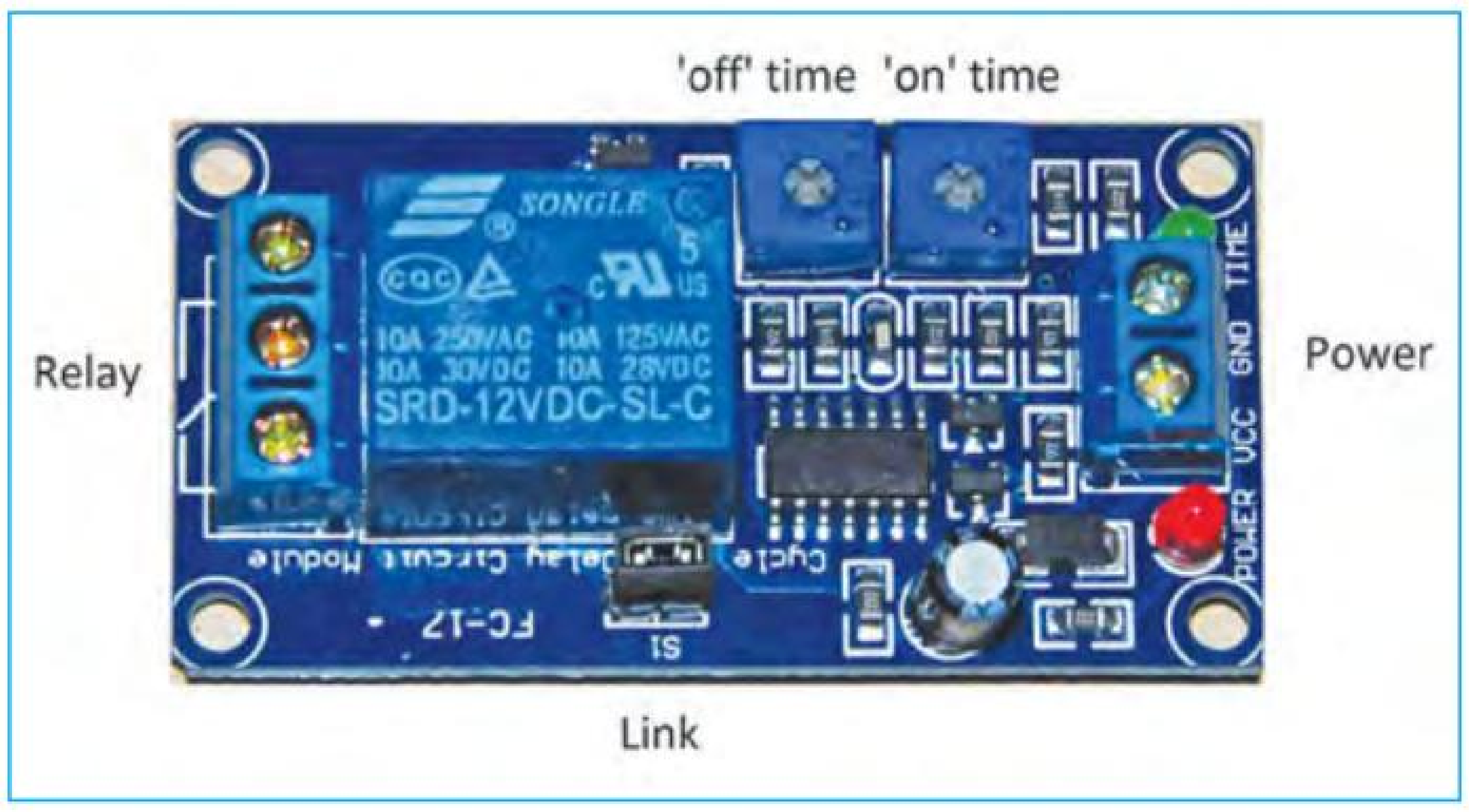


Fig.3. Pulsing Timer Module *link and pots*

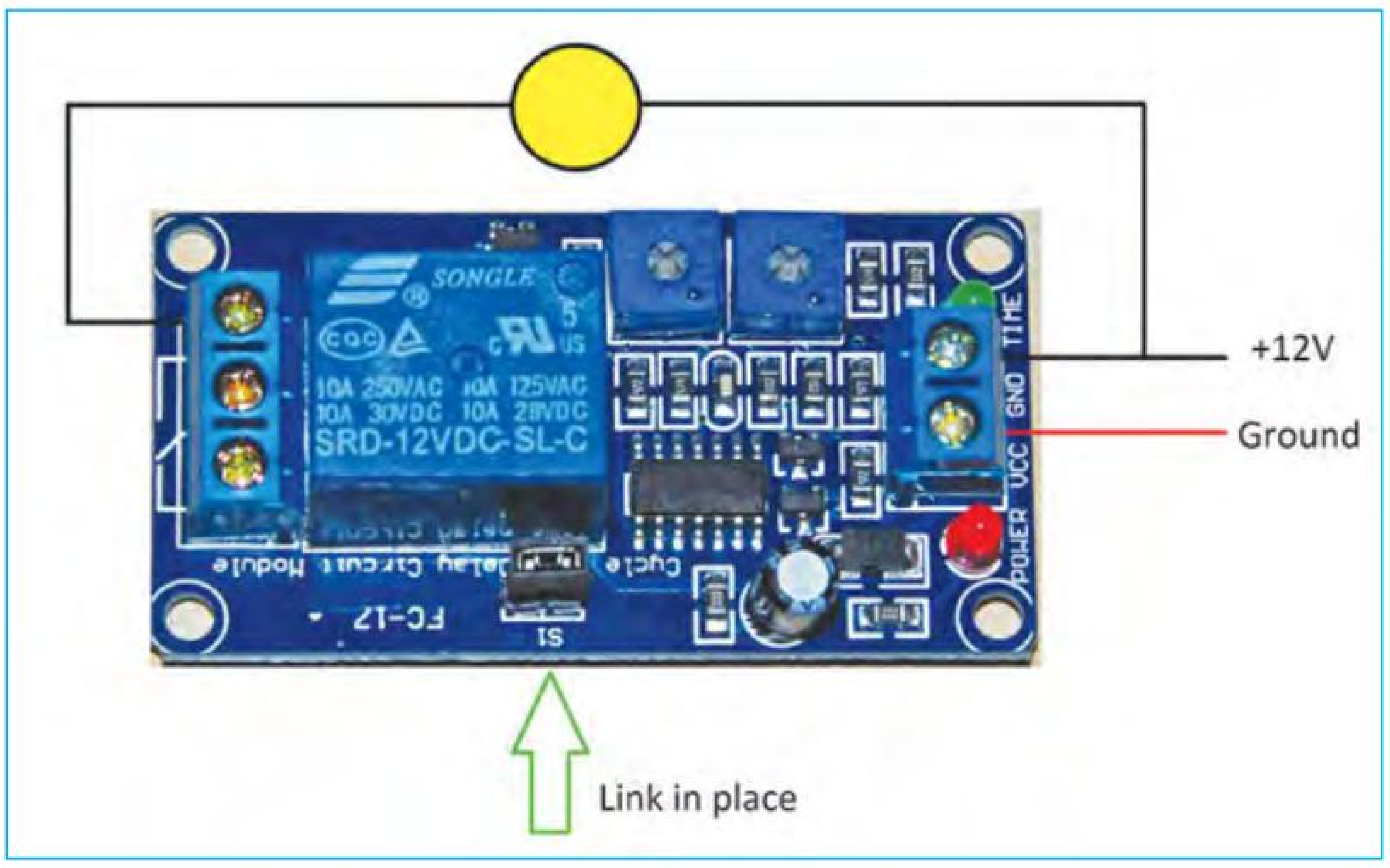


Fig.4. Pulsing Timer Module *wiring set-up for flashing a lamp*

the 'off' time was adjustable from 1 – 120 seconds, and the 'on' time from 1 – 40 seconds.

When the pots are adjusted correctly for the application, a dab of nail varnish can be used to hold them in the chosen positions.

Wiring

This diagram in Fig.4 shows the easiest wiring connections, where a lamp is being flashed. Power and ground are connected as shown. The light is wired between the normally open terminal of the relay and ground. The link (arrowed) is in place that directs +12V to the common terminal of the relay. The light then flashes whenever power is applied.

Conclusion

Wherever you want to pulse an output, think of this handy module!

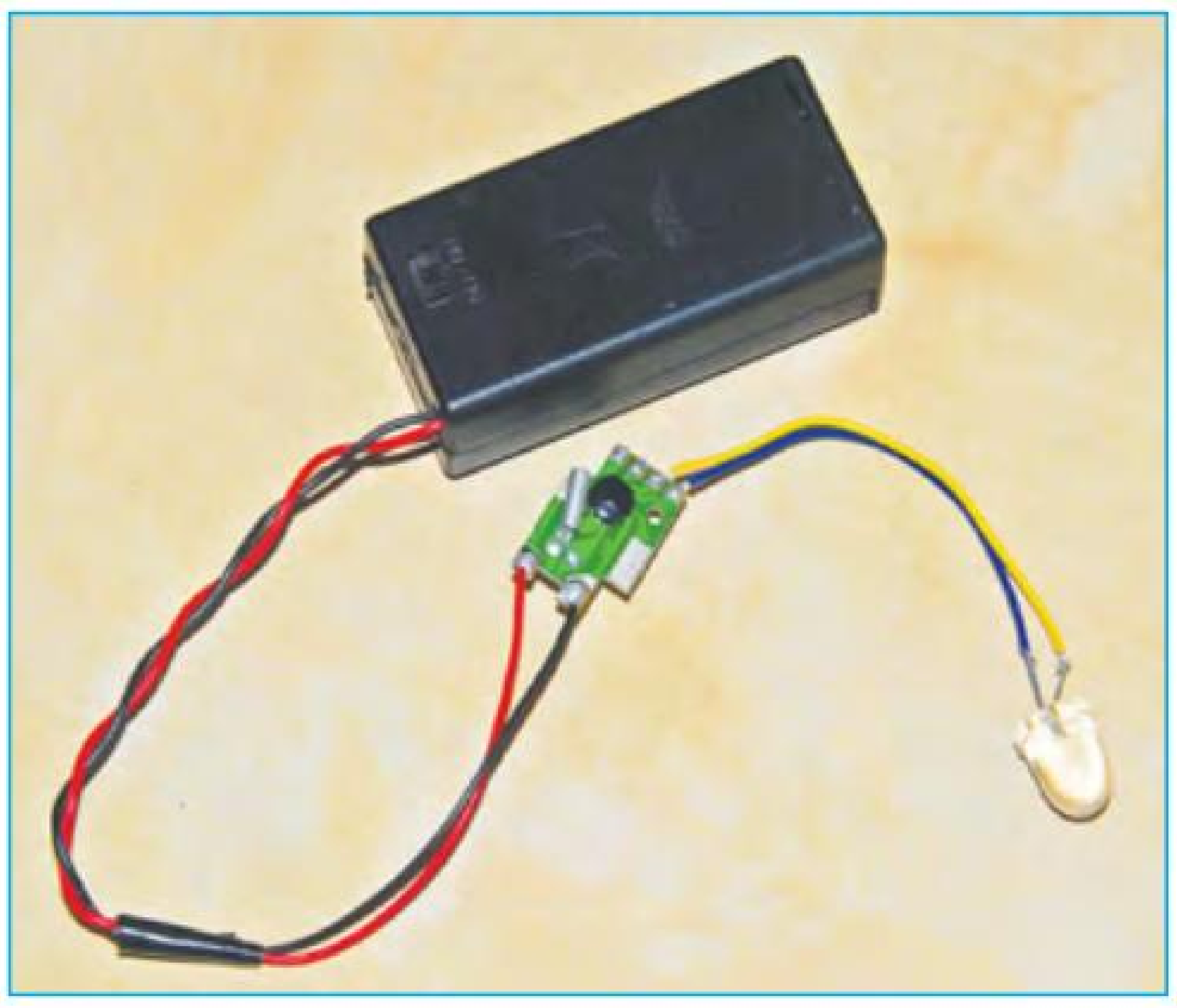
Sourcing

The module is available from China through eBay. Do a search under 'DC 12V SRD-12VDC-SL-C Circulate Time Delay Relay Module Blue'.) At the time of writing, a typical online unit is eBay item 191696964611 at a very reasonable £3.88 incl delivery.

Next month

Here's a project that ticks all the boxes – it costs nearly nothing, is very easy to build, and is extremely useful. So what is it? It's an *Ultra-low-current LED Flasher*, with the circuit board for this project taken straight from a battery-operated clock. All this is in our next super *Electronic Building Block* article.

Next month – Ultra-low-current LED Flasher



Get the answer you've been looking for

Vist the EPE Chat Zone
www.epemag.com
PICs?
Can anyone help me?
Problem sourcing software?
General Electronics chat
I Can help!

CRICKLEWOOD ELECTRONICS
Established 1981

Frustrated with your supplier?
Visit our component packed website for a vast range of parts - old and new, many unavailable elsewhere!
www.cricklewoodelectronics.com

1000's OF PRICES REDUCED!

Alternatively phone us on 020 8452 0161 with your requirements.

Visit our Shop, Call or Buy online at:
www.cricklewoodelectronics.com
020 8452 0161
Visit our shop at:
40-42 Cricklewood Broadway
London NW2 3ET

PCB SERVICE

CHECK US OUT ON THE WEB

Basic printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are drilled and roller tinned, but all holes are a standard size. They are not silk-screened, nor do they have solder resist. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. **NOTE: PCBs from the July 2013 issue with eight digit codes** have silk screen overlays and, where applicable, are double-sided, plated through-hole, with solder masks, they are similar to the photos in the relevent project articles.

All prices include VAT and postage and packing. Add £2 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

PROJECT TITLE	ORDER CODE	COST
NOV '14		
GPS Tracker	05112131	£13.15
DEC '14		
PortaPAL-D – Main PCB	01111131	£33.94
– Microphone Input	01111132	
– Guitar Input	01111133	
Electronic Bellbird	08112131	£11.53
JAN '15		
"Tiny Tim" Stereo Amplifier	01309111	£16.65
– Power supply	18110131	£11.80
FEB '15		
Audio Delay For PA Systems	01110131	£13.42
Teach-In 2015 – Part 1 Pre-Amp	905	£9.33
MARCH '15		
Stereo Echo & Reverb Unit	01110131	£13.42
Super Smooth, Full-range, 10A/230V Speed Controller for Universal Motors	10102141	£11.80
APRIL '15		
A Rubidium Frequency Standard For A Song	04105141	£8.02
USB/RS-232C Interface	07103141	£7.48
Teach-In 2015 – Part 3	906	£8.75
MAY '15		
Deluxe Fan Speed Controller	10104141	£10.72
RGB LED Strip Driver	16105141	£8.56
Low-cost Precision 10V DC Reference For Checking DMMs	04104141	£7.48
JUNE '15		
Burp Charge Your Batteries	14103141	£13.40
Teach-In 2015 – Part 5	907	£8.55
JULY '15		
L-o-o-o-n-g Gating Times For The 12-Digit High-Resolution Counter	04106141	£11.55
Threshold Voltage Switch	99106141	£10.15
Touch-Screen Digital Audio Recorder – Part 2	01105141	£13.70
AUG '15		
Nirvana Valve Simulator – Main PCB	01106141	£15.05
– Front Panel	01106142	£8.30
TempMasterMK3	21108141	£12.00
Teach-In 2015 – Part 7	908	£8.75
SEPT '15		
Opto-Theremin – Part 1		
– Main Theremin	23108141	£14.25
– Volume Control Board	23108142	£6.95
Mini-D Stereo 10W/Channel Class-D Audio Amplifier	01110141	£7.45
Wideband, Active Differential Oscilloscope Probe		
– Main PCB	04107141	£11.80
– Screening PCB	04107142	

PROJECT TITLE	ORDER CODE	COST
OCT '15		
Digital Effects Processor For Guitars And Musical Instruments	01110131	£16.40
Courtesy LED Lights Delay For Cars	05109141	£8.55
Teach-In 2015 – Part 9	909	£10.70
NOV '15		
The Currawong – Part 1		
– Main Board	01111141	£47.20
– Front Panel	01111142	£24.75
– Rear Panel	01111143	
48V Dual Phantom Power Supply	18112141	£9.37
Programmable Mains Timer With Remote Switching		
– Main Board	19112141	£11.80
– Front Panel	19112142	£16.40
DEC '15		
TDR Dongle For Oscilloscopes	04112141	£7.20
High-Energy Multi-Spark CDI For Performance Cars	05112141	£11.80
JAN '16		
Isolating High Voltage Probe For Oscilloscopes	04108141	£11.80
The Currawong – Part 3		
– Remote Control Board	01111144	£6.95
FEB '16		
Spark Energy Meter – Main Board	05101151	£20.75
– Zener Diode Board	05101152	
– Calibrator Board	05101153	£7.50

*** See NOTE left regarding PCBs with eight digit codes ***

Please check price and availability in the latest issue.
A large number of older boards are listed on, and can be ordered from, our website.
Boards can only be supplied on a payment with order basis.

EPE SOFTWARE

Where available, software programs for *EPE* Projects can be downloaded free from the Library on our website, accessible via our home page at: **www.epemag.com**

PCB MASTERS

PCB masters for boards published from the March '06 issue onwards are available in PDF format free to subscribers – email **fay.kearn@wimborne.co.uk** stating which masters you would like.

EPE PRINTED CIRCUIT BOARD SERVICE

Order Code	Project	Quantity	Price
. . . .	. . . .	. . . .	. . . .

Name . . . .
Address . . . .
. . . .
Tel. No. . . . .
I enclose payment of £ . . . . (cheque/PO in **£ sterling only**)
to:

Everyday Practical Electronics

Card No. . . . .
Valid From . . . . Expiry Date . . . .
Card Security No. . . . . Maestro Issue No. . . . . . .
Signature . . . .

Note: You can also order PCBs by phone, Fax or Email or via the Shop on our website on a secure server:
http://www.epemag.com

CLASSIFIED

ADVERTISEMENTS

If you want your advertisements to be seen by the largest readership at the most economical price our classified page offers excellent value. The rate for semi-display space is £10 (+VAT) per centimetre high, with a minimum height of 2·5cm. All semi-display adverts have a width of 5.5cm. The prepaid rate for classified adverts is 40p (+VAT) per word (minimum 12 words).

All cheques, postal orders, etc., to be made payable to Everyday Practical Electronics. **VAT must be added**. Advertisements, together with remittance, should be sent to Everyday Practical Electronics Advertisements, 113 Lynwood Drive, Merley, Wimborne, Dorset, BH21 1UU. Phone: 01202 880299. Fax: 01202 843233. Email: stewart.kearn@wimborne.co.uk. For rates and information on display and classified advertising please contact our Advertisement Manager, Stewart Kearn as above.

Everyday Practical Electronics reaches more UK readers than any other UK monthly hobby electronics magazine, our sales figures prove it. We have been the leading monthly magazine in this market for the last twenty-six years.

CANTERBURY WINDINGS
UK manufacturer of toroidal transformers
(10VA to 3kVA)
All transformers made to order. No design fees.
No minimum order.
www.canterburywindings.co.uk
01227 450810

BOWOOD ELECTRONICS LTD
Suppliers of Electronic Components
www.bowood-electronics.co.uk
Unit 10, Boythorpe Business Park, Dock Walk, Chesterfield,
Derbyshire S40 2QR. Sales: 01246 200 222
Send large letter stamp for Catalogue

SWITCHES & RELAYS
For full range Visit Section 19
www.partridgeelectronics.co.uk

MISCELLANEOUS

VALVES AND ALLIED COMPONENTS IN STOCK. Phone for free list. Valves, books and magazines wanted. Geoff Davies (Radio), tel. 01788 574774.

PIC DEVELOPMENT KITS, DTMF kits and modules, CTCSS Encoder and Decoder/Display kits. Visit **www.cstech.co.uk**

CAN ANYONE DECODE & RECODE my PIC16C55A; all info and expenses paid. Tel Mr Ward 01425 475445

EXTENSIVE LIST of IC's available. Transistor list available shortly. Please contact Dennis, tel. 0191 2520361

ADVERTISERS INDEX

BETA LAYOUT 80
CRICKLEWOOD ELECTRONICS 77
ESR ELECTRONIC COMPONENTS 6
EURO CIRCUITS 51
HAMMOND ELECTRONICS Ltd 17
JPG ELECTRONICS 80
LABCENTER . . . . Cover (iv)
LASER BUSINESS SYSTEMS 54
MICROCHIP . . . . Cover (iii) & 10
PCB CART . . . . Cover (ii)
PEAK ELECTRONIC DESIGN 5
PICO TECHNOLOGY 54
POLABS D.O.O. 30
QUASAR ELECTRONICS 2/3
RAPID 75
STEWART OF READING 57
VERO TECHNOLOGIES 19
WEARDALE ELECTRONICS 19

ADVERTISEMENT OFFICES:
113 LYNWOOD DRIVE, MERLEY, WIMBORNE,
DORSET BH21 1UU
PHONE: 01202 880299
FAX: 01202 843233
EMAIL: stewart.kearn@wimborne.co.uk
WEB: www.epemag.com
For editorial address and phone numbers see page 7

Next Month

Content may be subject to change

Modifying the Currawong Valve Amplifier

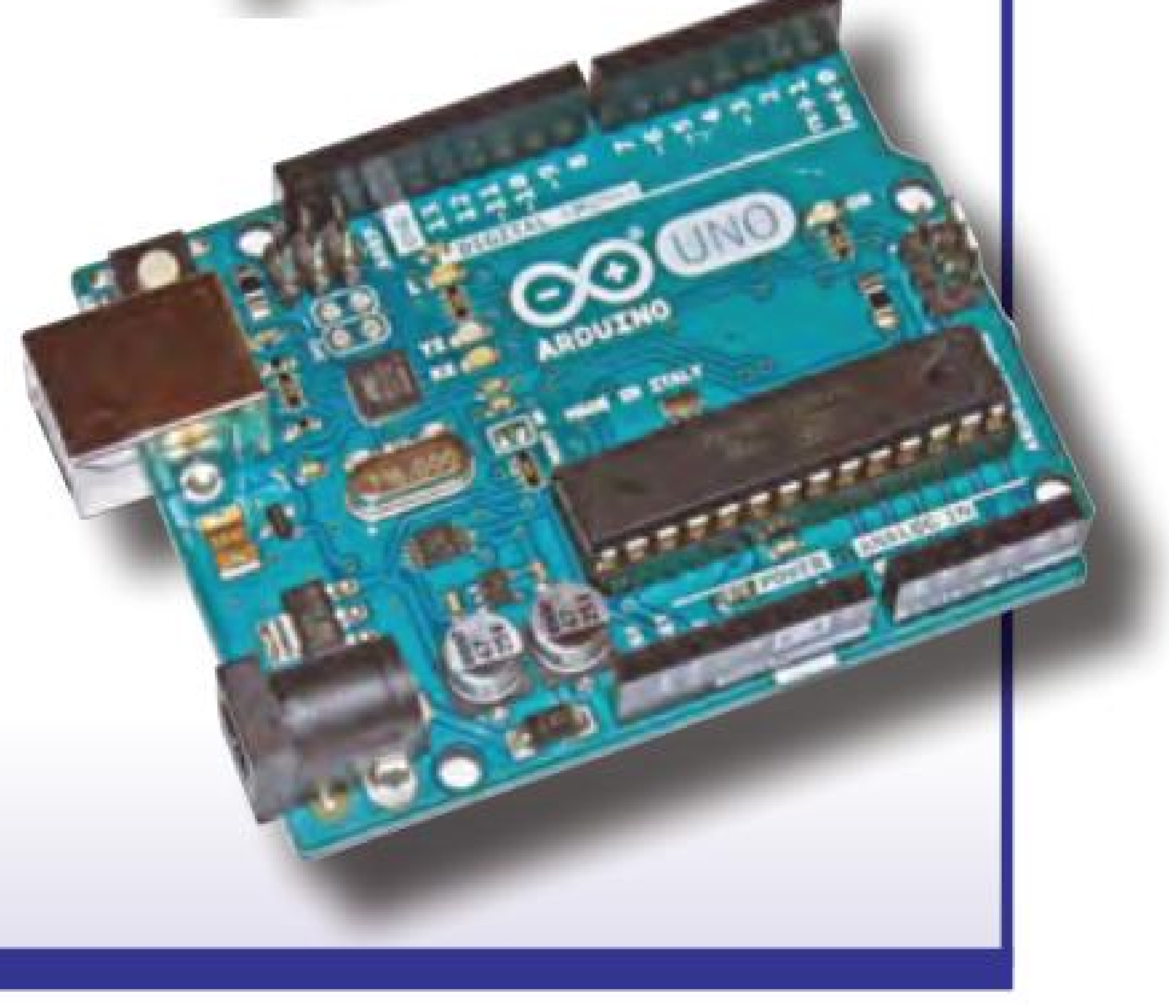
While the *Currawong Amplifier* has created a great deal of interest, some readers would like to see it with improved frequency response, better output transformers, more expensive valves and so on. We have investigated a number of these possibilities and you can judge for yourself whether all or any of the modifications discussed are worthwhile.

6-Digit Retro Nixie Clock – Part 2

This 6-digit *Nixie Clock* includes features such as GPS-locked time, date display, 7-day alarm, auto-dimming, 12/24 hour time and optional leading zero blanking. Having described the circuit and software operation in Part 1, next month we describe how to assemble it.

Spark Energy Meter – Part 2

Last month, we introduced our new *Spark Energy Meter*, an essential workshop tool for anyone who tinkers with automotive ignition systems – old or new! Now we get to the good bit: putting it all together.



Teach-In 2016 – Part 2

In February's *Teach-In 2016*, we will look at methods of connecting real-world hardware, including shields and add-on interface boards to drive mains-operated lamps and motors. We will also explain the structure and layout of program code and show you how to design and construct an Arduino-based door/window security system.

PLUS!

All your favourite regular columns from *Audio Out* and *Circuit Surgery* to *Electronic Building Blocks*, *PIC n' Mix* and *Net Work*.

MARCH '16 ISSUE ON SALE 4 FEBRUARY 2016

WELCOME TO JPG ELECTRONICS

Selling Electronics in Chesterfield for 29 Years

Open Monday to Friday 9am to 5:30pm
And Saturday 9:30am to 5pm

- Aerials, Satellite Dishes & LCD Brackets
- Audio Adaptors, Connectors & Leads
- BT, Broadband, Network & USB Leads
- Computer Memory, Hard Drives & Parts
- DJ Equipment, Lighting & Supplies
- Extensive Electronic Components
  - *ICs, Project Boxes, Relays & Resistors*
- Raspberry Pi & Arduino Products
- Replacement Laptop Power Supplies
- Batteries, Fuses, Glue, Tools & Lots more...

T: 01246 211 202
E: sales@jpgelectronics.com
JPG Electronics, Shaw's Row,
Old Road, Chesterfield, S40 2RB
W: www.jpgelectronics.com

Retail & Trade Welcome • Free Parking • Google St View Tour: S40 2RB

PANEL-POOL®
Beta LAYOUT

Custom Front Panels

Temperatursteuerung
Display
MAX
MIN
TEMP. MAX
TEMP. MIN
SENSOR 1
SENSOR 2
Alarm 1
Alarm 2
ENTER
ESC
CH1
CH2

Digital printing

Free Design Software

PANEL-POOL® is a registered trademark of Beta LAYOUT GmbH

www.panel-pool.com

Beta LAYOUT
create : electronics

Published on approximately the first Thursday of each month by Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Printed in England by Acorn Web Offset Ltd., Normanton, WF6 1TW. Distributed by Seymour, 86 Newman St., London W1T 3EX. Subscriptions INLAND: £23.50 (6 months); £43.00 (12 months); £79.50 (2 years). EUROPE: airmail service, £27.00 (6 months); £50.00 (12 months); £95.00 (2 years). REST OF THE WORLD: airmail service, £37.00 (6 months); £70.00 (12 months); £135.00 (2 years). Payments payable to "Everyday Practical Electronics'', Subs Dept, Wimborne Publishing Ltd. Email: subs@epemag.wimborne.co.uk. EVERYDAY PRACTICAL ELECTRONICS is sold subject to the following conditions, namely that it shall not, without the written consent of the Publishers first having been given, be lent, resold, hired out or otherwise disposed of by way of Trade at more than the recommended selling price shown on the cover, and that it shall not be lent, resold, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover by way of Trade or affixed to or as part of any publication or advertising, literary or pictorial matter whatsoever.

Analog is Everywhere

Power Management

- DC/DC Conversion
- System supervisors
- Battery charging
- Power measurement

Interface

- CAN, LIN, USB, I^{2}C, SPI, IrDA®
- Ethernet

Safety and Security

- Smoke Detection ICs (standard and custom)
- Piezoelectric horn drivers

Thermal Management

- Temperature sensors
- Fan controllers

Signal Conditioning

- Op Amps
- Comparators
- ADCs and DACs
- Digital potentiometers
- Instrumentation amps

LED Lighting

- Off-line
- DC/DC

www.microchipdirect.com

www.microchip.com/analog

The Microchip name and logo and the Microchip logo are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries. All other trademarks are the property of their registered owners.
© 2015 Microchip Technology Inc. All rights reserved. MEC2033Eng08/15

AUTODESK.
PTC
SOLIDWORKS

PROTEUS 8.3

ECAD to MCAD made easy

Data Exchange with STEP/IGES

The Proteus Design Suite now includes full support for data exchange with Mechanical CAD packages via the STEP/IGES file formats. This allows you to better visualise your design and helps quickly solve fixtures, fittings and casement problems.

Import 3D STEP/IGES models for your parts and visualise inside the Proteus Design Suite. Export your completed board to Solidworks or other MCAD software.

Visit www.labcenter.com
Tel:+44 01756753440 E-Mail info@labcenter.com

Labcenter Electronics Ltd, 21 Hardy Grange, BD23 5AJ

Labcenter Electronics www.labcenter.com